External Technical Review Report

Small Column Ion Exchange Technology at Savannah River Site

February 15, 2011

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LIST OF ACRONYMS

ARP	Actinide Removal Process
CD	Critical Decision
CPE	Common Plant Equipment
CSSX	Caustic Side Solvent Extraction
CST	Crystalline Silicotitanate
CTEs	Critical Technology Elements
CUA	Catholic University of America
DOE	U. S. Department of Energy
DOE-SR	DOE Savannah River
DSS	Decontaminated Salt Solution
DWPF	Defense Waste Processing Facility
EM-30	DOE Office of Technology Innovation and Development
ETR	External Technical Review
EOI	Expression of Interest
HLW	High Level Waste
ICD	Interface Control Document
IXC	Ion Exchange Column
LOI's	Lines of Inquiry
MCU	Modular CSSX Unit
MST	Monosodium Titanate
NAS	Alumino-silicate
ORNL	Oak Ridge National Laboratory
PCHA	Preliminary Consolidated Hazard Analysis
PDSA	Preliminary Documented Safety Analysis
PFD	Process Flow Diagram
RAMI	Reliability, Availability, Maintainability, and Inspectability

RFP	Request for Proposal
RMF	Rotary Micro-filter
ROAR	Risk and Opportunity Analysis Report
ROM	Rough Order of Magnitude
SCIX	Small Column Ion Exchange
SDS	Safety Design Strategy
SMP	Submersible Mixer Pumps
SPF	Saltstone Production Facility
SRD	Spent Resin Disposal
SRNL	Savannah River National Laboratory
SRR	Savannah River Remediation
SRS	Savannah River Site
SWPF	Salt Waste Processing Facility
TMP	Technology Maturation Plan
TR&C	Task Requirements and Criteria
TRA	Technology Readiness Assessment
TRL	Technology Readiness Level
TRU	Transuranics
WAC	Waste Acceptance Criteria
WTP	Hanford Waste Treatment Plant
VSL	Vitreous State Laboratory

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EXECUTIVE SUMMARY

An External Technical Review (ETR) was conducted on the Small Column Ion Exchange (SCIX) system planned to be deployed at the Savannah River Site (SRS). The SCIX system, which will demonstrate additional salt processing capability to the SRS Liquid Waste Program, is comprised of several associated components including an Ion Exchange Column (IXC), Rotary Micro-filter (RMF), Spent Resin Disposal (SRD), and Common Plant Equipment (CPE). The SCIX integrated system will be deployed in Tank 41H in the SRS Tank Farm. The strategy is to process an additional 2.5 million gallons per year of salt waste through the SCIX system deployed in Tank 41H for a period of approximately 10 to 12 years.

The SCIX development and deployment program is nearing the transition from concept finalization and planning to detailed design and procurement. Technology development initiatives have matured the SCIX technology to a system conceptual design stage. The deployment of the SCIX system is a key part of the enhanced tank waste strategy for SRS, and operations are forecast to begin at the end of 2013. Timely and successful deployment of the SCIX system could potentially result in significant schedule acceleration and life cycle cost reductions for the SRS Liquid Waste Program.

This ETR was chartered at the request of Yvette T. Collazo, Director of the Office of Technology Innovation and Development (EM-30). The ETR lead and the ETR team members are independent of EM-30, SRS organizations, and organizations involved in the development of SCIX. This ETR was specifically requested to ensure the maturity of the underpinning technologies of the process and readiness to complete the conceptual design phase currently in progress, such that the program can confidently move to the next phase of detailed design. The review targeted the critical technology elements (CTEs), as documented in the *Technology Maturation Strategy for the Small Column Ion Exchange Program* [1] (i.e. RMF, Ion Exchange, Grinder, and actinide removal steps) necessary to successfully deploy the SCIX system. The SCIX flowsheet and specific technology gaps identified to support SCIX system design and deployment by the end of 2013 were also assessed.

The ETR was performed in compliance with the *External Technical Review Process Guide* [2]. Thirteen Lines of Inquiry (LOIs), which are documented in the ETR charter, were identified and agreed to by the ETR team, the EM-30 sponsor, the Department of Energy Savannah River (DOE-SR) Program Manager, as well as the Savannah River Remediation (SRR) Program Manager. The results of the ETR, including observations and recommendations, are summarized in Table ES-1. The ETR process did not identify any observations in the "Severe Technical Issues" or "Technical Issues" categories. Several "Areas of Concern" and "Opportunities for Improvement" were identified, as well as some "Good Practices". The summary opinion of the ETR team is that the

SCIX system is mature enough to move to conceptual design, and that deployment by the end of 2013 is achievable. While there are some technology risks, these can be mitigated with appropriate testing and evaluation. For example, integrated testing of the entire system (i.e. four RMFs, two IXCs, etc.) should be performed, and testing should be conducted using representative simulants, at a minimum. However, the greatest risks to the program are related to schedule, particularly regarding procurement of long-lead items such as the RMFs. Additionally, integration of the SCIX system, coupled with start-up of the Salt Waste Processing Facility (SWPF) will introduce schedule risks for the overall Liquid Waste Program due to the increased salt processing in the Tank Farm requiring previously undemonstrated salt feed preparation rates, increased Saltstone production, and increased Tank Farm waste transfers. This is because these production demands must all be accomplished during the same time frame that sludge processing increases significantly in DWPF to meet increased canister production and waste loading goals.

Table ES-1. Summary of Observations and Recommendations

LOI #		Observations	Recommendations
	Technology LOIs		
1	Have technology studies been identified to support conceptual design and/or technology implementation decisions?	1. Good Practice: Technology maturity self assessments conducted. 2. Area of Concern: Timely completion of CTE component testing to allow for integrated testing.	1. N/A 2. Identify highest risk CTE validation testing and accelerate
2	Are prior EM-30 technology efforts being appropriately used to support conceptual design activities?	1. Good Practice: Full advantage and leveraging of past and ongoing EM-30 activities	1. N/A
3	Has the SCIX Program self-performed a technology maturity assessment to support design efforts and to identify technology gaps and risks for implementation? Has a technology roadmap, such as a Technology Maturation Plan, that includes costs and schedules been developed and implemented with adequate resources?	1. Area of Concern: Technology Maturation Plan (TMP) [3] does not include cost and schedule data for maturation. 2. Opportunity for Improvement: TMP does not include discussion of risk associated with each CTE.	1. Include maturation schedules and Rough Order of Magnitude (ROM) cost estimates in the (TMP) [3]. 2. Include risk details in TMP associated with each CTE.
4	Are plans in-place to perform relevant prototypic large scale testing prior to actual radioactive field deployment?	1. Area of Concern: Surrogate for CST in grinding tests may not be representative. 2. Area of Concern: Timely completion of CTE component testing to allow for integrated testing. Need to better understand coupled flow dynamics of components. 3. Area of Concern: Not clear if water or simulant will be used for integrated testing.	1. Conduct more rigorous physical comparison of chabazite to CST. 2. Accelerate CTE validation to initiate integrated testing as soon as possible. 3. Identify appropriate and representative simulants, which should be used for integrated testing.

LOI #		Observations	Recommendations
5	Has the waste that will be processed been adequately characterized?	The waste from the tanks currently planned to be processed using SCIX have be adequately characterized. There are no observations for LOI #5.	1. N/A.
6	Have disposal paths been identified for all wastes including secondary waste streams?	1. Good Practice: All primary and secondary SCIX process waste streams identified and appropriate disposition paths. 2. Area of Concern: Removal and disposition of failed equipment and components does not appear to be adequately addressed.	1. N/A 2. Removal and disposition plans for failed/spent RMFs. SRDs, IXCs, Submersible Mixer Pumps (SMPs), etc. should be developed as soon as possible, or provided to the ETR team if they exist.
7	Have technology activities to support safety basis development been identified and included in the technology roadmap?	1. Area of Concern: Preliminary Consolidated Hazard Analysis (PCHA) identifies several Open Issues and Analyses To Be Performed. 2. Opportunity for Improvement: Safety Analysis review team result was thorough and comprehensive but could have been more independent.	1. Develop a plan for completion with schedules and include in the SCIX Program Schedule or Technology Maturation Plan 2. N/A
8	Is the technology sufficiently mature to support conceptual design activities and the transition to detailed design?	1. Area of Concern: Crystalline Silicotitanate (CST) ion exchange technology has been extensively researched with adequate kinetic, thermodynamic, and thermal analysis. Would be beneficial to validate thermal modeling with mock-up column. 2. Area of Concern: RMF technology appears to be well developed and ready to be included in a conceptual design. However, its impact on IXC performance has not been experimentally investigated. 3. Opportunity for Improvement: Two viable grinder technologies were presented to the review team. Down-selection has since occurred.	1. Investigate options for validating thermal column model using artificial heat sources in lieu of radioactive decay. 2. An appropriately scaled integrated test involving RMF and IXC units operating in line would be beneficial for assessing processing sensitivity to realistic flow variations. 3. Basis for this down-selection and potential impact on the rest of this process should be documented.

LOI #		Observations	Recommendations
	Design LOIs		
9	Has the SCIX Program defined the technical requirements and criteria necessary for conceptual design?	1. Area of Concern: It is agreed that process control evaluation is an important issue. It is particularly important given the in-series configuration of the RMF and IXC units. 2. Area of Concern: One of the additional studies mentioned, related to thermal modeling. It is stated in the TR&C document to determine bounding thermal conditions in the ion exchange column and the waste tank. However, the thermal model has not been experimentally validated. 3. Area of Concern: See LOI #8 Observation #1. 4. Area of Concern: A more integrated approach to testing IXC-RMF interaction is needed.	1. Model fluid flow between the RMF and IXC units and validate experimentally if possible. 2. As mentioned in LOI #8, thermal testing would increase confidence in the thermal model for the IXC. 3. Perform a truly integrated test linking at least one RMF unit to at least one IXC unit. Flow affects as well as cross contamination issues can be explored.
10	Is conceptual design progressing and are schedules, including technical issue resolution, in place and reasonably achievable?	1. Area of Concern: Some delays have been experienced in completion of technical reports. Additional testing may be identified in revisions of the recently completed Technology Maturity Plan [3]. Any new technology gaps and technical risks that may be identified must be given sufficient resources to ensure timely resolution.	1. Ensure sufficient resources are provided to complete the planned evaluations, analyses, and testing (including emergent work) in time to support design and engineered equipment procurement.
11	Are programmatic risks, including technical risks and issue resolution, identified and appropriate risk mitigation activities identified and incorporated into SCIX Program schedules to provide a reasonable confidence of deployment by the end of 2013?	1. Area of Concern: Although recommended, it is not clear that appropriate simulants will be used for integrated testing. 2. Area of Concern: Overall SCIX schedule is very aggressive and relies on vendor performance for key components. 3. Area of Concern: Ability of the Liquid Waste System to provide adequate feed and the SPF to produce Saltstone at needed rate has never been demonstrated.	1. See LOI #4 Observation 3 Recommendation. 2. Ensure that the highest risk components are identified and testing, validation, and procurements are planned and scheduled to ensure on-time availability.. 3 Ensure the feed preparation and saltstone throughput risks are addressed appropriately in risk documents and program schedules.

LOI #		Observations	Recommendations
12	Has integration of the SCIX system with existing systems, equipment, and processes been adequately addressed and impacts identified?	1. Area of Concern: Ability of the Liquid Waste System to provide adequate feed and the SPF to produce Saltstone at needed rate has never been demonstrated. Increased salt work in Tank Farm must be achieved during same time frame as increased sludge transfers and processing in DWPF. Combined needs may overwhelm the actual Tank Farm capability.	1. Develop system integration plans that track progress to ensure maximum salt feed and saltstone production rates can be achieved.
13	Have reliability, availability, maintainability, and inspectability of the SCIX system been adequately addressed to ensure successful implementation and operation?	1. Area of Concern: Appropriate Reliability, Availability, Maintainability, and Inspectability (RAMI) planning has been documented and some validation tasks initiated; however it will not be completed until February 2011; once the RAMI is completed it should be reviewed to verify that no changes to the ETR are indicated.	1. The RAMI report should be completed as soon as possible, and this area should be re-evaluated once it is available, either by this ETR team, or in upcoming assessments and reviews.

Note that the Observation categories are based on the following definitions excerpted from the *ETR Process Guide* [2].

<u>**Observation Categories Used for SCIX ETR**</u>

- Severe Technical Issues – Observations that would prevent the technology from being fully developed to meet mission needs. These observations should be considered fatal flaws that cannot be resolved.
- Technical Issues – Observations requiring resolution to ensure the technology will successfully meet mission needs.
- Areas of Concern – Observations that may require design modifications to the technology deployment or additional testing to resolve technical concerns.
- Opportunities for Improvement – Observations that would improve the ability to meet mission needs or offer alternative solutions to technical problems.
- Good Practices - Items that are commendable and deserve recognition.

It should also be noted that during the time of the initial visit by the ETR team to SRS during September 21-23, 2010, several key SCIX Program documents and test reports were in the process of being completed. Many of these contain information that is necessary to conduct a proper ETR. A decision was made to delay completion of the ETR report as much as possible, from November 8, 2010, to December 16, 2010. This provided an opportunity for the ETR team to have access to the information in many of those key documents, resulting in a more comprehensive review. Of the 19 identified documents, 14 had been received at the time of this report. The ETR was completed with the information available, although some areas may have to be re-evaluated in upcoming assessments and/or reviews.

External Technical Review
Small Column Ion Exchange Technology at Savannah River Site

1. INTRODUCTION

An External Technical Review (ETR) was conducted on the Small Column Ion Exchange (SCIX) system planned to be deployed at the Savannah River Site (SRS). The SCIX system, which will demonstrate additional salt processing capability to the SRS Liquid Waste Program, is comprised of several associated components including an Ion Exchange Column (IXC), Rotary Micro-filter (RMF), Spent Resin Disposal (SRD), and Common Plant Equipment. The SCIX integrated system will be deployed in Tank 41H in the SRS Tank Farm. The strategy is to process an additional 2.5 million gallons per year of salt waste through the SCIX system deployed in Tank 41H for a period of approximately 10 to 12 years.

The SCIX Development and Deployment Program is nearing the transition from concept finalization and planning to detailed design and procurement. Technology development initiatives have matured the SCIX technology to a system conceptual design stage. The deployment of the SCIX system is a key part of the enhanced tank waste strategy for SRS, and operations are forecast to begin at the end of 2013. Timely and successful deployment of the SCIX system could potentially result in significant schedule acceleration and life cycle cost reductions for the SRS Liquid Waste Program, assuming that the salt waste feed is available to take advantage of the capabilities of the system.

This ETR was chartered at the request of Yvette T. Collazo, Director, Office of Technology Innovation and Development (EM-30). The charter document defining the full scope of this ETR is included as Attachment 1. The ETR lead and the ETR team members, whose biographical sketches are included in Attachment 2, are independent of EM-30, SRS organizations, and organizations involved in the development of SCIX. The Common Plant Equipment, which will be used in the SCIX system to perform the same functions as in existing SRS Tank Farm systems, was specifically **not** a focus of this review.

This ETR was specifically requested to ensure the maturity of the underpinning technologies of the process and readiness to complete the conceptual design phase currently in progress, such that the program can confidently move to the next phase of detailed design. The scope of the review targeted the critical technology elements (CTEs), as documented in the *Technology Maturation Strategy for the Small Column Ion Exchange Program* [1] (i.e., RMF, Ion Exchange, Grinder, and actinide removal steps) necessary to successfully deploy the SCIX system. The SCIX flowsheet and specific technology gaps identified to support SCIX system design and deployment by the end of 2013 were assessed also.

Note that the SCIX Program is an Operations Activity, and specifically not a project, as defined by DOE Order 413.3A, *Program and Project Management for the Acquisition of Capital Assets* [4].

Nevertheless, the SCIX Program team is using the DOE Guide 413.3-4, *Technology Readiness Assessment Guide* [5], to structure the technology maturation and deployment process, providing greater opportunity for success. Additionally, the SCIX Program has determined that the IXC and SRD portions of the program are each designated as a "major modification," and thus the program team is applying DOE-STD-1189-2008 *Integration of Safety into the Design Process* [6].

The ETR was performed in compliance with the *External Technical Review Process Guide* [2]. Thirteen LOIs, which are documented in the ETR charter, Attachment 1, and defined below, were identified and agreed to by the ETR team, the EM-30 sponsor, the DOE-SR SCIX Program Manager, and the SRR SCIX Program Manager.

The LOIs are categorized as "Technology" or "Design." The "Technology" LOIs are focused on the maturity of the CTEs and other key process aspects of the technology, including integration of these components. The "Design" LOIs are focused on the actual conceptual design and implementation of the SCIX system and how it integrates with and impacts other existing systems. Some areas of overlap do exist within the LOIs, so an exact and clear distinction is not always possible, or even desirable. Accordingly, the LOIs have been addressed with the intent to provide the most useful and complete review information to the SCIX Program team for consideration.

Although the LOIs are documented in the Charter document, they are also included here for clarity and completeness.

1.1. Technology Lines of Inquiry

1. Have technology studies been identified to support conceptual design and/or technology implementation decisions?
2. Are prior EM-30 technology efforts being appropriately used to support conceptual design activities?
3. Has the SCIX Program self-performed a technology maturity assessment to support design efforts and to identify technology gaps and risks for implementation? Has a technology roadmap, such as a Technology Maturation Plan, that includes costs and schedules been developed and implemented with adequate resources?
4. Are plans in-place to perform relevant prototypic large scale testing prior to actual radioactive field deployment?
5. Has the waste that will be processed been adequately characterized?
6. Have disposal paths been identified for all wastes including secondary waste streams?
7. Have technology activities to support safety basis development been identified and included in the technology roadmap?
8. Is the technology sufficiently mature to support conceptual design activities and the transition to detailed design?

1.2. Design Lines of Inquiry

1. Has the SCIX Program defined the technical requirements and criteria necessary for conceptual design?
2. Is conceptual design progressing and are schedules, including technical issue resolution, in place and reasonably achievable?
3. Are programmatic risks, including technical risks and issue resolution, identified and appropriate risk mitigation activities identified and incorporated into SCIX Program schedules to provide a reasonable confidence of deployment by the end of 2013?
4. Has integration of the SCIX system with existing systems, equipment, and processes been adequately addressed and impacts identified?
5. Have reliability, availability, maintainability, and inspectability of the SCIX system been adequately addressed to ensure successful implementation and operation?

1.3. External Technical Review Process

As previously indicated, this ETR was conducted in accordance with the *External Technical Review Process Guide* [2]. As part of the review process, the ETR team visited SRS during September 21-23, 2010. During this visit the team was provided with detailed presentations of the SCIX system, including the overall system description and purpose, CTE descriptions, downstream impacts, ongoing technology maturation efforts, design criteria and requirements, and risk assessments and management efforts. Additionally, tours were provided of the Savannah River National Laboratory (SRNL) testing facilities for the RMF and the tenth scale mixing tank. During the presentations and tours, areas were identified by the ETR team that required additional information and supplemental presentations and discussions were provided by the SCIX Program team. The SCIX Program team consists of representatives from the DOE-SR, SRR, and SRNL.

Because the scope of the review and the LOIs were agreed upon prior to the site visit, the presentations, discussions, and tours were specifically structured to help address the LOIs. The SCIX Program team provided an agenda for the site visit, which is included as Attachment 3. During the site visit, the ETR team realized that several key technical and programmatic documents were in the process of being developed or revised. Many of these documents were considered necessary for the ETR team to conduct a valid review. Therefore, the decision was made to delay completion of the ETR, and thus the resulting report, until the necessary information in the documents was available. The schedule was revised as follows:

December 2, 2010 Draft report submitted to DOE-SR for factual review (was October 25, 2010)

December 8, 2010 DOE-SR returns comments to Team (was November 1, 2010)

February 10, 2011 Final Report Issued (was November 8, 2010)

February 24, 2011 DOE-SR issues Issue Response Plan (was December 2, 2010)

This schedule was believed to be more appropriate in view of the timing of the initial site visit and expected availability of most of the requested documents. This schedule resulted in a much more comprehensive and useful ETR.

The ETR team identified a total of 19 documents that were either necessary or useful for the review process. To date, 14 of the 19 documents have been provided to the ETR team by the SCIX Program. Additional documents may be provided during finalization of this report. The ETR was completed with the information available, although some areas may have to be re-evaluated in upcoming assessments and/or reviews. Any new information that is germane to the overall results will be included, to the extent practical. The support and responsiveness of the SCIX Program team has been excellent and much appreciated by the ETR team.

2. BACKGROUND

The SRS Tank Farms function as concentration, storage, and transfer facilities for radioactive liquid waste. Since SRS began operations in the early 1950's, its uranium (U) and plutonium (Pu) recovery processes have generated liquid radioactive waste. Approximately 37 million gallons of liquid radioactive waste is stored in 49 underground tanks in 'F' and 'H' Areas. Tank space is critical to the success of this mission and to the eventual implementation of strategies to process the tank waste inventories, which will enable final closure of the Tank Farms.

The radioactive liquid waste stored in SRS tanks is broadly characterized as either "sludge waste" or "salt waste." Sludge waste is water insoluble and settles to the bottom of a waste tank, typically beneath a layer of liquid supernatant, commonly referred to as "supernate". The sludge represents only about 8% of the SRS tank waste volume (~2.9 million gallons) but contains 53% of the radioactivity (~169 million curies). The salt waste, which represents about 92% of the SRS tank waste volume (~34.2 million gallons) and 48% of the radioactivity (~183 million curies), exists as supernate (in normal solution) or "saltcake" (previously dissolved salts, such as sodium nitrate and sodium nitrite, that have now crystallized out of solution). A single waste tank can contain sludge, supernate, and salt cake. However, SRS liquid waste handling and evaporation practices have resulted in tanks that contain mostly sludge and tanks that contain mostly saltcake. For purposes of this ETR, the salt cake and supernate will be generally referred to as salt waste. See Figure 2.1.

Figure 2.1. Salt Waste, supernate (upper) and salt cake (lower)[7]

2.1. Salt Waste Processing

The SWPF is the planned facility that will remove cesium from Tank Farm salt solutions using the Caustic Side Solvent Extraction (CSSX) process, while Sr and actinides (i.e., transuranics [TRU]) will be removed through treatment with MST and filtration. Extensive testing and evaluation was completed that resulted in the down- select of the technologies that constitute the SWPF flowsheet. Four alternatives were originally considered, which included CSSX, ion exchange, small tank precipitation, and direct to grout.

The ion exchange technology, which was under evaluation for the SWPF deployment, was a large column design using CST resin. This technology was not selected primarily due to heat concerns in a loaded column of CST of the size large enough to meet the throughput requirements of SWPF. Other alternatives were eliminated for various reasons, and the CSSX process was ultimately chosen as the technology for SWPF. The analysis of the various alternatives is summarized in the document titled

Supplemental Analysis: Salt Processing Alternatives at the Savannah River Site [8].

The previous Liquid Waste System Plan, Rev. 15 [9] has sludge processing complete approximately six years prior to salt processing, thus requiring vitrification in the DWPF of salt waste only during this period, which is highly inefficient. This significantly increases the lifecycle cost for liquid waste treatment. The SCIX system described below, in combination with improvements to SWPF, provides supplemental salt processing capacity meant to bring salt and sludge processing endpoints into alignment, resulting in potential significant schedule acceleration of six years and cost savings of $3B. See Figure 2.2, which is excerpted from the presentation titled *Liquid Waste System Plan and Supplemental Salt Processing Initiative* [7], which was provided to the ETR team. This is the primary purpose for the SCIX system development and deployment, as well as justification for the investment required, which is estimated at $130M.

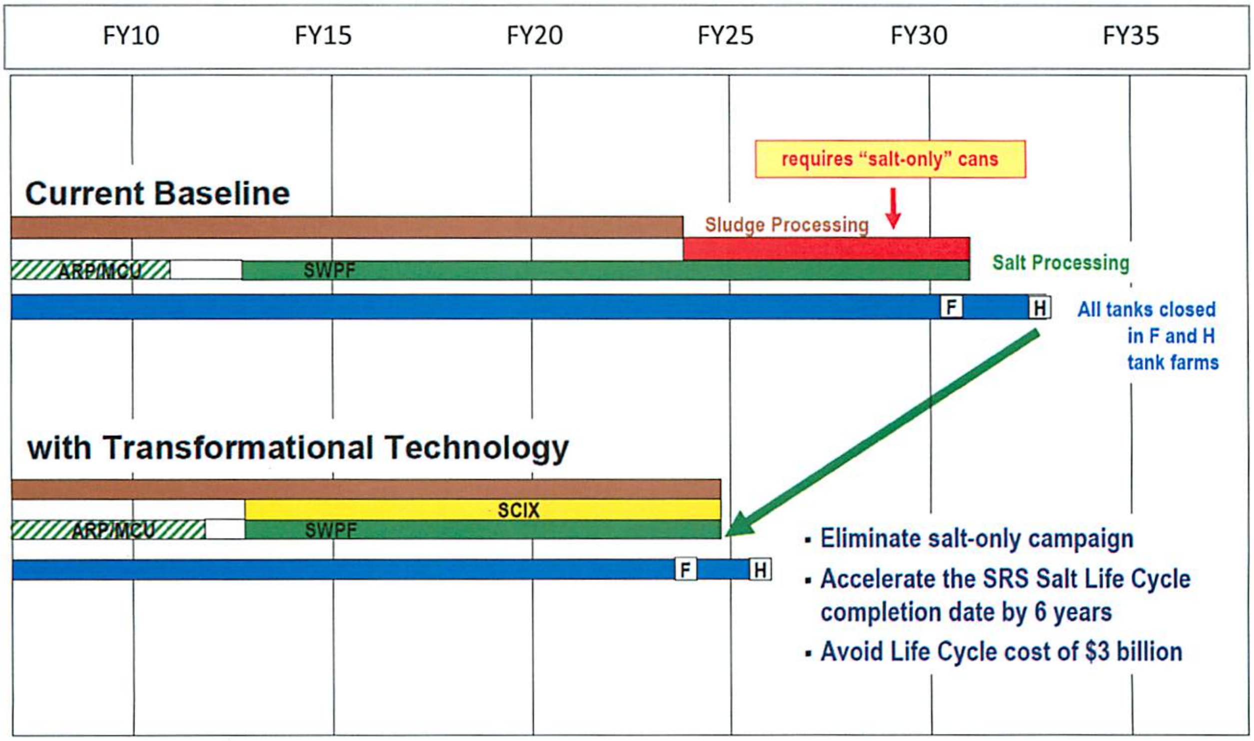


Figure 2.2. Baseline acceleration projected from SCIX deployment estimated at $130M. [7]

2.2. SCIX System Description

As previously discussed, the SCIX system will provide additional salt processing capability to accelerate salt processing from, and closure of, waste tanks. The SCIX process is scheduled to operate in parallel with the SWPF to supplement the overall salt processing capability at SRS, thus eliminating six years of "salt waste only" vitrification in DWPF.

The SCIX process, which will be installed in various risers in Tank 41H, consists of one feed pump, four RMFs, two IXC units, and one SRD unit. Figure 2.3 provides a rendering of the proposed system to be installed in the tank.

The basis for sizing the RMF and IXC is to eliminate the salt-only DWPF canisters from the lifecycle. This requires an additional 2.5 million gallons per year of salt solution treatment capacity above the SWPF capacity. Assuming continuous operation at 75% availability, this requires a nominal SCIX processing rate of 10 gallons per minute.

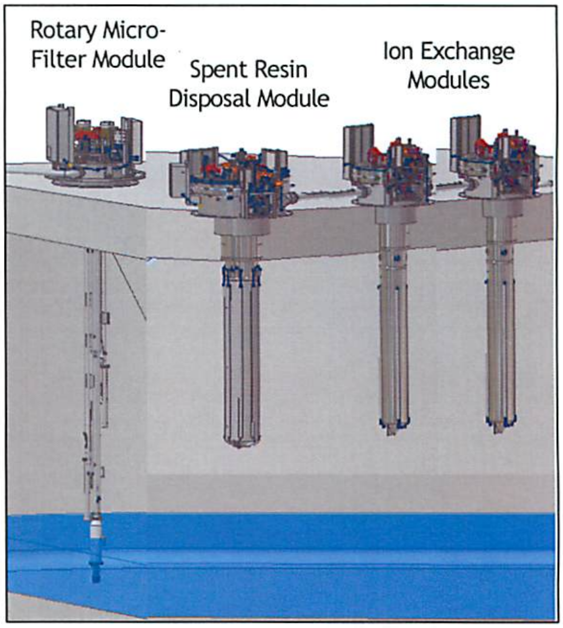


Figure 2.3. SCIX System Modules in a Waste Tank [11]

Prior to processing through the IXCs, MST slurry will be mixed with the salt solution to adsorb the Sr and actinides in the salt solution. Then, this MST-laden salt solution must be filtered prior to passing through the IXCs to remove the MST and insoluble solids in the feed stream, which would foul the IXCs if not removed. Removal of the actinides is also required to meet the Saltstone Production Facility (SPF) Waste Acceptance Criteria (WAC). The MST and insoluble sludge solids are expected to collect in the bottom of Tank 41H for later transfer to Tanks 42H or 51H and ultimate immobilization at DWPF.

The SCIX effluent, referred to as decontaminated salt solution (DSS), will be transferred to Tank 50H and then later transferred to the SPF for eventual disposal as grout in the Saltstone Disposal Facility (SDF).

The SCIX process uses a non-elutable ion exchange media, CST, in the IXC to remove the cesium-137 (^{137}Cs) from the salt solution. As previously mentioned, CST was originally evaluated as an option for the SWPF but was eliminated due to heat issues associated with the large-scale loaded IXC. The smaller design for in-riser applications eliminates this heating problem, which has been verified through efforts by SRNL [12, 13]. Figure 2.4 shows a timeline of the sequence of events leading up to the decision to implement the SCIX Program, and to the selection of CST.

Once the CST is loaded with ^{137}Cs, the spent media must be removed and the IXC replenished with fresh resin. Spent CST will be sluiced to the SRD to reduce the particle size. The ground CST, laden with ^{137}Cs, is then transferred to a sludge batch for ultimate immobilization in borosilicate glass at DWPF. The spent CST must be ground to facilitate transfer to Tank 40H to enable re-suspension of the ground CST for transfer from Tank 40H to DWPF. The complete SCIX system is depicted graphically in Figure 2.5.

Figure 2.4. SCIX Program Implementation and CST Selection Timeline [3]

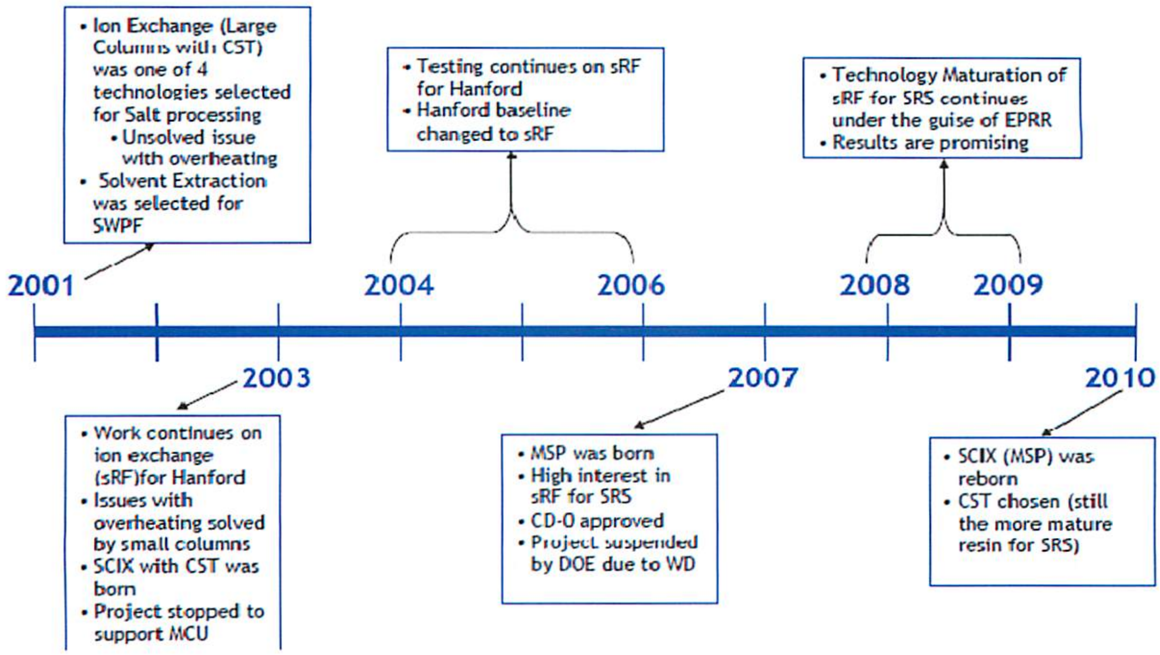
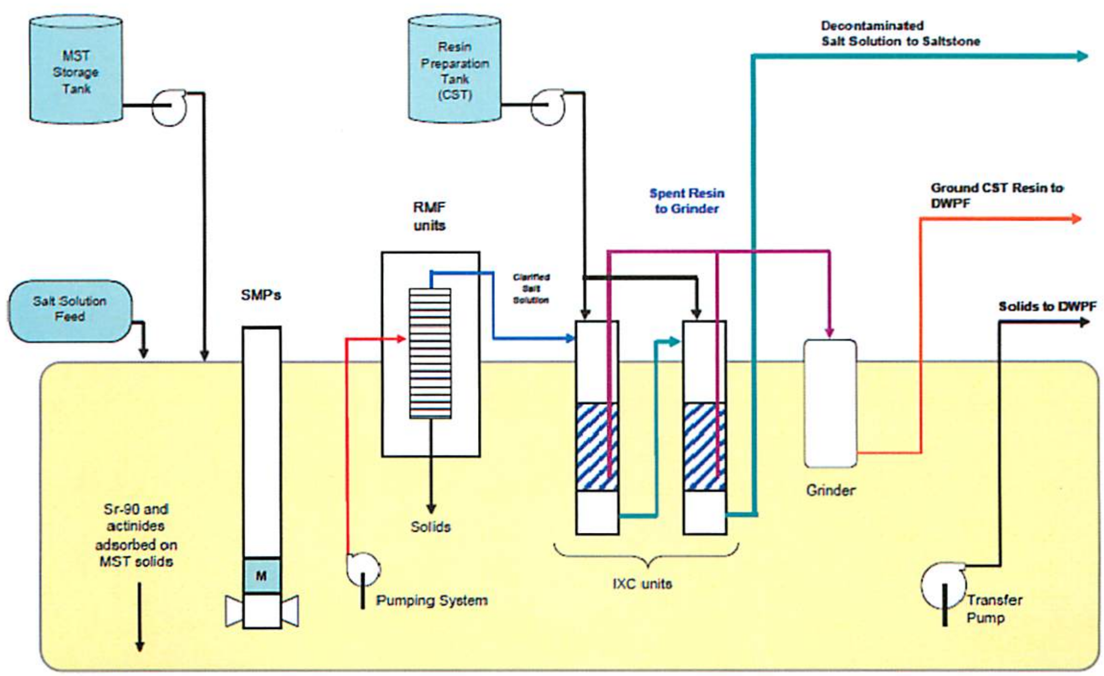


Figure 2.5. Baseline SCIX Program Process Diagram [3]



3. OBSERVATIONS AND RECOMMENDATIONS

The results of the ETR, including observations and recommendations, are summarized and discussed in detail in this section. The ETR process did not identify any observations in the "Severe Technical Issues" or "Technical Issues" categories. Several "Areas of Concern" and "Opportunities for Improvement" were identified, as well as some "Good Practices". The summary opinion of the ETR team is that there are some technology risks but these can be mitigated with appropriate testing and evaluation. For example, integrated testing of the entire system (i.e. four RMFs, two IXCs, etc.) should be performed and testing should be conducted using representative simulants at a minimum. However, the greatest risks to the program are related to schedule, particularly regarding procurement of long-lead items such as the RMFs. Additionally, integration of the SCIX system, coupled with start-up of the SWPF, will introduce schedule risks for the overall Liquid Waste Program due to the fact that the increased salt processing in the Tank Farm will require previously undemonstrated salt feed preparation rates, increased Saltstone production, and increased waste transfers in the Tank Farm. This is because these production demands must all be accomplished during the same time frame that sludge processing increases significantly in DWPF to meet increased canister production and waste loading goals.

3.1. Summary of Review Results – Observations and Recommendations

Table 3.1 provides a summary of the observations and recommendations identified by the ETR team. Section 3.2, below, provides the details of these findings.

Table 3.1 Summary of SCIX ETR Team Observations and Recommendations for the LOIs

LOI #		Observations	Recommendations
	Technology LOIs		
1	Have technology studies been identified to support conceptual design and/or technology implementation decisions?	1. Good Practice: Technology maturity self assessments conducted. 2. Area of Concern: Timely completion of CTE component testing to allow for integrated testing.	1. N/A 2. Identify highest risk CTE validation testing and accelerate
2	Are prior EM-30 technology efforts being appropriately used to support conceptual design activities?	1. Good Practice: Full advantage and leveraging of past and ongoing EM-30 activities	1. N/A
3	Has the SCIX Program self-performed a technology maturity assessment to support design efforts and to identify technology gaps and risks for implementation? Has a technology roadmap, such as a Technology Maturation Plan, that includes costs and schedules been developed and implemented with adequate resources?	1. Area of Concern: Technology Maturation Plan (TMP) [3] does not include cost and schedule data for maturation. 2. Opportunity for Improvement: TMP does not include discussion of risk associated with each CTE.	1. Include maturation schedules and Rough Order of Magnitude (ROM) cost estimates in the (TMP) [3]. 2. Include risk details in TMP associated with each CTE.

LOI #		Observations	Recommendations
4	Are plans in-place to perform relevant prototypic large scale testing prior to actual radioactive field deployment?	1. Area of Concern: Surrogate for CST in grinding tests may not be representative. 2. Area of Concern: Timely completion of CTE component testing to allow for integrated testing. Need to better understand coupled flow dynamics of components. 3. Area of Concern: Not clear if water or simulant will be used for integrated testing.	1. Conduct more rigorous physical comparison of chabazite to CST. 2. Accelerate CTE validation to initiate integrated testing as soon as possible. 3. Identify appropriate and representative simulants, which should be used for integrated testing.
5	Has the waste that will be processed been adequately characterized?	The waste from the tanks currently planned to be processed using SCIX have be adequately characterized. There are no observations for LOI #5.	1. N/A.
6	Have disposal paths been identified for all wastes including secondary waste streams?	1. Good Practice: All primary and secondary SCIX process waste streams identified and appropriate disposition paths. 2. Area of Concern: Removal and disposition of failed equipment and components does not appear to be adequately addressed.	1. N/A 2. Removal and disposition plans for failed/spent RMFs. SRDs, IXCs, Submersible Mixer Pumps (SMPs), etc. should be developed as soon as possible, or provided to the ETR team if they exist.
7	Have technology activities to support safety basis development been identified and included in the technology roadmap?	1. Area of Concern: Preliminary Consolidated Hazard Analysis (PCHA) identifies several Open Issues and Analyses To Be Performed. 2. Opportunity for Improvement: Safety Analysis review team result was thorough and comprehensive but could have been more independent.	1. Develop a plan for completion with schedules and include in the SCIX Program Schedule or Technology Maturation Plan 2. N/A
8	Is the technology sufficiently mature to support conceptual design activities and the transition to detailed design?	1. Area of Concern: Crystalline Silicotitanate (CST) ion exchange technology has been extensively researched with adequate kinetic, thermodynamic, and thermal analysis. Would be beneficial to validate thermal modeling with mock-up column. 2. Area of Concern: RMF technology appears to be well developed and ready to be included in a conceptual design. However, its impact on IXC performance has not been experimentally investigated. 3. Opportunity for Improvement: Two viable grinder technologies were presented to the review team. Down-selection has since occurred.	1. Investigate options for validating thermal column model using artificial heat sources in lieu of radioactive decay. 2. An appropriately scaled integrated test involving RMF and IXC units operating in line would be beneficial for assessing processing sensitivity to realistic flow variations. 3 Basis for this down-selection and potential impact on the rest of this process should be documented.

LOI #		Observations	Recommendations
	Design LOIs		
9	Has the SCIX Program defined the technical requirements and criteria necessary for conceptual design?	1. Area of Concern: It is agreed that process control evaluation is an important issue. It is particularly important given the in-series configuration of the RMF and IXC units. 2. Area of Concern: One of the additional studies mentioned, related to thermal modeling. It is stated in the TR&C document to determine bounding thermal conditions in the ion exchange column and the waste tank. However, the thermal model has not been experimentally validated. 3. Area of Concern: See LOI #8 Observation #1. 4. Area of Concern: A more integrated approach to testing IXC-RMF interaction is needed.	1. Model fluid flow between the RMF and IXC units and validate experimentally if possible. 2. As mentioned in LOI #8, thermal testing would increase confidence in the thermal model for the IXC. 3. Perform a truly integrated test linking at least one RMF unit to at least one IXC unit. Flow affects as well as cross contamination issues can be explored.
10	Is conceptual design progressing and are schedules, including technical issue resolution, in place and reasonably achievable?	1. Area of Concern: Some delays have been experienced in completion of technical reports. Additional testing may be identified in revisions of the recently completed Technology Maturity Plan [3]. Any new technology gaps and technical risks that may be identified must be given sufficient resources to ensure timely resolution.	1. Ensure sufficient resources are provided to complete the planned evaluations, analyses, and testing (including emergent work) in time to support design and engineered equipment procurement.
11	Are programmatic risks, including technical risks and issue resolution, identified and appropriate risk mitigation activities identified and incorporated into SCIX Program schedules to provide a reasonable confidence of deployment by the end of 2013?	1. Area of Concern: Although recommended, it is not clear that appropriate simulants will be used for integrated testing. 2. Area of Concern: Overall SCIX schedule is very aggressive and relies on vendor performance for key components. 3. Area of Concern: Ability of the Liquid Waste System to provide adequate feed and the SPF to produce Saltstone at needed rate has never been demonstrated.	1. See LOI #4 Observation 3 Recommendation. 2. Ensure that the highest risk components are identified and testing, validation, and procurements are planned and scheduled to ensure on-time availability. 3 Ensure the feed preparation and saltstone throughput risks are addressed appropriately in risk documents and program schedules.

LOI #		Observations	Recommendations
12	Has integration of the SCIX system with existing systems, equipment, and processes been adequately addressed and impacts identified?	1. Area of Concern: Ability of the Liquid Waste System to provide adequate feed and the SPF to produce Saltstone at needed rate has never been demonstrated. Increased salt work in Tank Farm must be achieved during same time frame as increased sludge transfers and processing in DWPF. Combined needs may overwhelm the actual Tank Farm capability.	1. Develop system integration plans that track progress to ensure maximum salt feed and saltstone production rates can be achieved.
13	Have reliability, availability, maintainability, and inspectability of the SCIX system been adequately addressed to ensure successful implementation and operation?	1. Area of Concern: Appropriate Reliability, Availability, Maintainability, and Inspectability (RAMI) planning has been documented and some validation tasks initiated; however it will not be completed until February 2011; once the RAMI is completed it should be reviewed to verify that no changes to the ETR are indicated.	1. The RAMI report should be completed as soon as possible, and this area should be re-evaluated once it is available, either by this ETR team, or in upcoming assessments and reviews.

Note that the Observation categories are based on the following definitions excerpted from the *ETR Process Guide* [2].

<u>Observation Categories Used for the SCIX ETR</u>

- Severe Technical Issues – Observations that would prevent the technology from being fully developed to meet mission needs. These observations should be considered fatal flaws that cannot be resolved.
- Technical Issues – Observations requiring resolution to ensure the technology will successfully meet mission needs.
- Areas of Concern – Observations that may require design modifications to the technology deployment or additional testing to resolve technical concerns.
- Opportunities for Improvement – Observations that would improve the ability to meet mission needs or offer alternative solutions to technical problems.
- Good Practices - Items that are commendable and deserve recognition.

3.2. Detailed Review Results

The following provides more detailed discussion of the results of the ETR. The LOIs are organized by either technology focus or design focus, as previously defined. For each LOI, the discussion includes the condition at the time of review, any observations, related recommendations, and benefit of the recommended action, as appropriate.

3.2.1. Technology Lines of Inquiry

The "Technology" LOIs are focused on the maturity of the CTEs and other key process aspects of the technology, including integration of these components.

3.2.1.1. LOI #1. Have technology studies been identified to support conceptual design and/or technology implementation decisions?

Condition at Review

The SCIX Program has identified four CTEs: small column ion exchange to remove radioactive cesium using CST ion exchange media; filtration to separate solids from liquids using the RMF; actinide (and ^{90}Sr) removal using MST; and size reduction of the CST using a grinder (the SRD). The use of CST for Cs removal from SRS radioactive liquid waste has been extensively studied for more than ten years [14]. A commercially available RMF technology has been modified by SRS and successfully tested at full scale for over 1,500 hours with SRS liquid waste simulants and at small scale with actual SRS liquid waste from the Tank Farms. MST technology development and testing with SRS High Level Waste (HLW) and HLW simulants has spanned more than ten years. The technology is currently employed in treatment of SRS HLW in the SRS Actinide Removal Process (ARP) Facility.

The SCIX Program conducted an informal technology assessment in March of 2010 that identified technology gaps and was used to initiate technology development work. In August 2010 the program issued a Technology Maturation Strategy [1]. In September 2010 the Program conducted a technology self assessment using DOE Technology Readiness Assessment (TRA) methodology that determined the current Technology Readiness Level (TRL) for each CTE and identified additional technology gaps. In October 2010 the Program issued a Technology Maturation Plan [3] that summarized the technology gaps and the additional work required to achieve TRL 6.

Table 3.2 lists the work required in the TMP to bring all CTEs to TRL 6. Activities in black were identified during the March 2010 initial assessment. Activities in red were identified during the September 2010 self-assessment. Some of the activities impact multiple CTEs. Technology maturation requires completion of activities in three areas: technology development (proof that the technology works); manufacturing quality (proof that the components and materials can be reliably manufactured); and programmatic (proof that all Federal, State and DOE programmatic requirements have been completed and documented).

Table 3.2 Work Required to Achieve Technology Readiness Level 6 for the SCIX Program

Work Required to Achieve TRL 6

Note: Because the SCIX Program is a program, and not a project, DOE O 413.3A project management requirements, including the Critical Decision (CD) process, do not apply. However, the SCIX Program has elected to follow this more rigorous approach, which is commendable. Per 413.3A, TRL 4 is required for conceptual design (CD-1), and TRL 6 for final design (CD-2). This table was excerpted from the TMP, but includes updated status information, as appropriate.

Technology / Technical Aspects	
Issue Conceptual Design Package	Five conceptual design packages were issued in November: CPE, IXC, RMF, SRD, and Truss; final design is in progress.
Conduct Thermal Modeling	Work at SRNL to determine the bounding thermal conditions in the ion exchange column and in the waste tank under normal and upset conditions has been completed; report has been issued.
Conduct Sodium Alumino-silicate (NAS) Formation Studies	Work at SRNL to understand the conditions that form NAS so that blend strategies can be developed to prevent its formation in the ion exchange columns. Report has been issued; additional work recommended.
Conduct Loading Studies	Work at SRNL to determine the maximum loading for actinides on CST and MST and the maximum loading for cesium on CST. Reports have been issued; additional work recommended.
Conduct Mixing Studies	Work at SRNL to determine type and number of pumps required for SCIX processing. Work is in progress.
Conduct DWPF Impact Studies (Glass/Processability)	Work at SRNL to determine the impacts of SCIX on DWPF processing and glass. Work is in progress.
Evaluate Gas Purging and Disengagement	Evaluate if gas purging and disengagement is an issue requiring additional scope.
Issue Final Grinding / Sluicing Recommendation	Final report from Energy Solution/Vitreous State Laboratory (VSL) documenting recommendation on grinder technology and results of pumping / sluicing tests. Grinder recommendation report has been issued. Pumping test has been completed; sluicing test will be conducted in early 2011. Final report documenting results of pumping/sluicing tests will follow.
Receive Vendor Response to Request for Proposal (RFP)	Request for proposals will be sent out to interested vendors. Responses to the RFPs from vendors will document their interest and ability to fabricate the unit (RMF, SRD, IXC).
Validate RMF Performance with CST	Testing to be conducted by SRNL to confirm CST fines do not pass through the RMF. This test will be conducted in early 2011.
Validate RMF Control Scheme	Testing to be conducted by SRNL to validate running multiple parallel units from one control station. This test will be conducted in early 2011.

Table 3.2 Continued Work Required to Achieve Technology Readiness Level 6 for the SCIX Program

Programmatic Aspects	
Issue Risk and Opportunities Assessment Report (ROAR)	This report addresses risks and opportunities associated with SCIX. It presents the risks and levels of risk associated with the program, risk handling strategies to be employed, residual risk remaining, and program opportunities. This report has been issued.
Document Exit Criteria	Exit criteria will be reaching a TRL of 6 as documented in the Technology Maturation Plan.
Issue Conceptual Design Package	This work has already been defined above.
Obtain DOE Approval on Proposal	Proposals for SCIX installation and operations have been submitted to DOE for approval. This will allocate funds to do work identified in the TMP.
Complete Vendor Design	Completion of unit design by the vendor.
Receive Vendor Response to RFP	This work has already been defined above.
Issue Configuration Management Plan	This plan defines the strategy and execution activities for configuration management of SCIX Program documents. It will be used by SCIX Program personnel who establish and make changes to program documentation and physical configuration. This plan has been issued.
Conduct RAMI Analysis	Analysis of SCIX system components will be conducted to validate the assumed SCIX attainment (75%). A preliminary RAMI Analysis has been completed based on conceptual design. A more detailed RAMI Analysis will be completed as part of final design.
Issue Task Requirements and Criteria Document Revision, incorporating changes from PCHA	This is a revision to the Task Requirements and Criteria (TR&C) document (design input) to incorporate requirements from the SCIX PCHA. Revision 2 of the TR&C has been issued.
Issue Interface Control Document (ICD)	This document will define the administrative interfaces associated with the design, installation, and operation of SCIX. This document has been issued.
Issue Final Technical Report on Technologies	Summary report of technology work to support a TRL of 6.
Issue Preliminary Documented Safety Analysis (PDSA)	The SCIX Program design strategy is to develop conceptual and final design documentation. The scope for the SCIX process is considered a Major Modification; therefore, a PDSA is required. The PDSA will be approved upon completion of final design. Changes to the DSA will be made after approval of the PDSA. This is consistent with DOE Order 1189.
Conduct Loading Studies	Defined above.
Conduct Mixing Tests	Defined above.
Validate RMF Performance with CST	Defined above.
Validate RMF Control Scheme	Defined above.
Issue Final Grinding/Sluicing Recommendation	Defined above.

Table 3.2 Continued Work Required to Achieve Technology Readiness Level 6 for the SCIX Program

Manufacturing / Quality Aspects	
Complete Integrated Testing	This test will involve testing of the actual equipment to be installed in Tank 41H (SRD, IXC, and RMF) and will be conducted at SRS.
Receive Expression of Interest (EOI) Response from Vendor	An EOI will be used to solicit the industry, develop a bidders list, and identify possible inputs to the procurement specification. EOI for IXC has been issued and responses received.
Conduct RAMI Analysis	Defined above.
Issue ROAR	Defined above.
Complete Vendor Design	Defined above.
Complete Vendor Fabrication	Completion of unit fabrication by the vendor.
Complete 1,000-hr RMF Test	1,000-hr full scale RMF endurance test with sludge simulants conducted at SpinTek. This test was successfully completed on 10/10/10.
Validate RMF Performance with CST	Defined above.
Validate RMF Control Scheme	Defined above.
Issue Final Grinding/Sluicing Recommendation	Defined above.

The SCIX Program self assessment TRA found that the technology aspects of the four CTEs were at TRL 4 including one type of grinding apparatus. However, the SCIX Program decided to further investigate some alternative grinding technologies that were at TRL 3. The manufacturing/quality aspects were judged to be at TRL 3 and the programmatic aspects at TRL 2 for all CTEs. Thus, the overall TRL for the SCIX Program would thus be TRL 2.

LOI #1 Observation 1: Good Practice

The SCIX Program has conducted both an informal and formal self-assessment of the technology maturity of the SCIX system. This has resulted in early identification of the technology studies required to support conceptual design and/or technology implementation decisions. Several of the required studies involving technical aspects sufficient for conceptual design (TRL 4) have already been completed. The SCIX deployment is an "Operations Activity" and not a project, as defined in DOE O 413.3A. Nevertheless, the SCIX Program has decided to follow the more rigorous technology maturity assessment and maturation process of 413.3A, which is commendable.

LOI #1 Observation 2: Area of Concern

Significant work remains to be completed on the SCIX technical, programmatic and manufacturing/quality aspects to support conceptual design and/or technology implementation decisions. When work on the items in Table 3.2 is completed, all four CTEs should be at TRL 6. Integrated testing is included in the SCIX Program Schedule.

Recommendation: If possible, accelerate testing and validation of highest risk CTEs and integration points. This will provide more time to conduct integrated testing of highest risk areas.

Benefit: Risk reduction to the program deployment schedule, which is already aggressive.

3.2.1.2. LOI # 2. Are prior EM-30 technology efforts being appropriately used to support conceptual design activities?

Condition at Review

Extensive work has been done on using MST and CST to remove radionuclides from highly alkaline salt solutions. MST is used to remove TRU elements (primarily Pu and neptunium [Np]) and strontium-90 (^{90}Sr), while CST is used to remove ^{137}Cs (but can also remove ^{90}Sr). The SCIX Program is relying heavily on the existing body of knowledge that has been generated on the MST and CST technologies through various activities funded by EM. Both MST and CST were extensively studied for application in the treatment of salt wastes at Savannah River during the down-select of technologies for the SWPF. An excellent summary of the results of work conducted at that time can be found in Dimenna et al. [15].

The MST technology was chosen as the baseline for TRU/Sr removal in the SWPF. Subsequently, MST was actually put into practice in the ARP. It appears that this previous experience will be utilized by the SCIX Program to support conceptual design. The primary difference between the SWPF and ARP applications of MST versus the SCIX application is that in the latter, the MST strike will be conducted in a 1 million gallon waste storage tank, which is not specifically designed for the MST operation.

The CST technology was not chosen for application in the SWPF, primarily because of concerns of over-heating of the loaded CST material in the large columns required. The SCIX process is intended to eliminate this concern by using the CST in small columns in which the temperature can be better controlled. The SCIX concept was first investigated at Oak Ridge National Laboratory (ORNL) [16] and has been extensively evaluated both at ORNL and at Savannah River. Clearly, all of this previous work is being used in the conceptual design activities. SRS personnel provided the ETR team with a list of approximately 55 documents being used to support the SCIX application of CST.

The use of the RMF in the SCIX application is less developed than the MST and CST. However, researchers at SRNL have been at the forefront of developing this technology for nuclear service since 2003. These researchers have been, and currently are, funded by EM to further develop the RMF technology. Hence, it can reasonably be concluded that the EM technology development efforts (prior and existing) are being appropriately used to support conceptual design.

The SRD system (resin sluicing and grinding) is for the most part a matter of technology selection rather than technology development. Similar operations have previously been deployed in-tank at SRS. A list of 14 references was provided by the SCIX personnel regarding prior work on the spent resin disposal system.

LOI #2 Observation 1: Good Practice

The SCIX Program appears to be taking full advantage of the applicable prior EM-funded research and development efforts, as well as being actively engaged with EM-30 in accomplishing the identified technology maturity activities.

3.2.1.3. LOI #3. Has the SCIX Program self-performed a technology maturity assessment to support design efforts and to identify technology gaps and risks for implementation? Has a technology roadmap, such as a Technology Maturation Plan, that includes costs and schedules been developed and implemented with adequate resources?

Condition at Review

As noted in the response to LOI #1, the SCIX Program has performed a technology maturity self assessment using the TRA methodology [5] and has also published a technology maturation strategy [1]. The Program has completed two risk assessment documents, a pre-mortem [17] and a ROAR [18], which analyze technical and programmatic risks.

LOI #3 Observation 1: Area of Concern

The current TMP is more a report of the self-assessment than a TMP. These efforts appear to have adequately identified the technology gaps for implementation, and it is clear that technology maturation activities are ongoing and/or planned. However, the specific descriptions of work in progress and additional work planned to mature each CTE are absent. Additionally, the TMP does not include schedules or estimates of the costs for maturing the CTEs or detailed discussion of the technical risks involved in maturing each CTE.

Recommendation: A more detailed TMP should be prepared that describes work planned and in progress, a schedule, and a ROM (at a minimum) cost estimate for each CTE. The TMP should also describe in some detail full scale, prototypical, and integrated testing that will be carried out.

Benefit: Risk reduction of cost and schedule.

LOI #3 Observation 2: Opportunity for Improvement

Generalized technology risks have been integrated into the ROAR. However, the ROAR does not contain detailed discussions of the risks involved in developing each CTE.

Recommendation: Risks involved in the technology maturation of each CTE should also be included in the TMP, or ROAR, as appropriate.

Benefit: Technical risk reduction for CTE maturation and deployment.

3.2.1.4. LOI #4. Are plans in-place to perform relevant prototypic large scale testing prior to actual radioactive field deployment?

Condition at Review

There are a number of plans in place to perform relevant prototypic large scale testing of selected unit operations before radioactive field deployment. These include a 1000-hour RMF test (this test was in progress at the time of the review meeting, and has subsequently been completed), grinding and sluicing tests, factory acceptance testing, and an integrated non-radioactive test of actual equipment at the TNX facility. In addition, pilot-scale tests of various pumps for suspending and re-suspending the MST sorbent material are being performed.

Testing has recently concluded on a full-scale 25-disk RMF assembly as described in the test plan by Herman et al. [19]. This testing was conducted at SpinTek using a tank waste simulant. The RMF was tested at 5 wt % insoluble solids for the first 362 hours, 10 wt % insoluble solids for the next 640 hours, and then 15 wt % solids for the last part of the test. Some issues involving chipping of the journal bearing were encountered during the testing, but these were eventually resolved. At 663 hours, the filter disks were cleaned *in situ* with nitric acid cleaning which restored the filtration rate to almost 90% of the initial clean disk rate. Eighty liters of 0.2 M nitric acid in conjunction with water rinses were used to clean the filter in less than 2 hours. After the 1000 hours of run time was completed, the filter was continued to be run. Since the bearing material was changed during the test, it was decided to continue running the filter and obtain 1000 hours of run time with the new bearing material. At that point the other filter components actually were tested for over 1500 hours of run time.

Testing of the CST sluicing and grinding systems is being conducted by the VSL of the Catholic University of America (CUA) [20]. The sluicing tests will essentially be full scale, using a natural zeolite material (chabazite) with properties similar to those of CST. The equipment used for the sluicing tests will incorporate all engineering features that are believed to be significant with regards to the sluicing operation. As currently planned, the grinding tests will use a scaled immersion mill which will be tested in a tank scaled to simulate the relatively narrow riser configuration. The scaled matching of the mill size with the tank size will allow testing of the effectiveness of the self-circulation in the scaled riser geometry. Both batch and continuous flow grinding tests will be conducted. Testing of an inline dispenser grinder and particle-size reduction through sonication is also being investigated. Scaled testing of pumping of the ground chabazite will also be performed.

A report from the grinder testing has been issued [21]. Based on the initial evaluation, EnergySolutions/VSL recommended that SRR proceed with the Hockmeyer immersion mill as the preferred design concept for the SCIX application. The results from the testing of the Hockmeyer immersion mill were somewhat compromised by the fact that the chabazite used was pre-ground to a greater extent than anticipated when supplied to the vendor for testing. A number of excellent recommendations were made on p. 26 of Mohr [21] for further evaluation of the technology. These recommendations should be pursued.

As part of the SCIX process, MST will be added to the feed material in Tank 41H to remove actinides and ^{90}Sr. During the sorption phase, mixer pumps will be run to keep the MST solids suspended. Mixing will be stopped and the MST will settle to some degree during processing of the feed through the RMF and the CST columns. Pilot-scale testing is being done to help guide the choice of the mixer pumps to be used. This testing is being done in an acrylic tank that is approximately $1/10^{th}$ geometrically scaled to Tank 41H. The test tank is also equipped with models of the tank cooling coils. The pilot-scale testing has three primary objectives: 1) to determine the pump parameters required to initially suspend the MST during the actinide/Sr sorption phase, 2) to determine the time required to sorb Sr onto the MST, and 3) to determine the pump parameters required to remobilize the MST for removal from Tank 41H. The three primary conditions being examined are MST in salt solution, MST plus CST in salt solution, and MST plus CST plus sludge in salt solution. The pumps examined are the submersible mixing pump, the quad volute pump, and a standard pump. For testing of initial suspension, the MST is allowed to settle overnight at 25°C, whereas, for mimicking re-suspension for removal from the tank, the MST solids are allowed to settle for four weeks at 45°C. Preliminary results from these tests suggest that the submersible mixing pump is the best pump option and that three such pumps will be needed to mobilize the MST material for transfer out of Tank 41H.

Before actual radioactive deployment in Tank 41H, all of the required SCIX equipment will undergo a series of acceptance tests, and integrated non-radioactive testing of the equipment is planned before installation in tank. The details of these tests are not yet available. One issue that will need to be resolved is whether the integrated non-radioactive tests will include an actual demonstration of the Cs removal using CST.

<u>LOI #4 Observation 1: Area of Concern</u>

The grinding tests are being done using chabazite as a surrogate for CST, which may not be representative for all process parameters.

Recommendation: More rigorous physical comparison of the chabazite to CST should be done to build confidence that chabazite is an appropriate simulant for this purpose. Issues to address are the friability, whether CST grinds to a bimodal particle size distribution similar to chabazite, and the relative propensity of chabazite for form fines compared to CST. See recommendations provided on pg 26 of Mohr [21].

Benefit: Technical risk reduction by verifying the lower cost simulant for CST is representative in key process parameters.

LOI #4 Observation 2: Area of Concern

The current VSL scope does not include full-scale integrated testing of the sluicing, grinding, and product transfer system. This is stated to be done later as part of the design activities.

Recommendation: Investigate opportunities to accelerate testing and modeling to understand the interactions and fluid dynamics of the system; for example, the coupling of four RMF units with two ion exchange columns. (See LOI #1 Observation #2 Recommendation.)

Benefit: Technical risk reduction of the integrated system. Risk reduction associated with the aggressive program schedule.

LOI #4 Observation 3: Area of Concern

A full scale integrated SCIX test is planned to be completed using the equipment that will be deployed in tank. It is not clear what type of test fluid will be used for this demonstration. Some discussion during the onsite review indicated that water may be considered.

Recommendation: The full scale integrated testing should be done with a representative simulant that includes non-radioactive cesium. This will allow verification of the equipment performance before tank installation.

Benefit: Technical risk reduction of the integrated system.

3.2.1.5. LOI #5. Has the waste that will be processed been adequately characterized?

Condition at Review

The waste contained in tanks at SRS consists of salt supernate, salt cake, and sludge. The plan is to process salt supernate and interstitial liquid, totaling about 27 million gallons of salt solution. The annual throughput for the SCIX process is cited as 2.5 million gallons per year. This is roughly consistent with with the cited operating duration of 10 years. Waste characterization data was made available for tank 49H (ARP/MCU Salt Batch 1, 2, and 3 [22, 23, 24]), and for tanks 41, 37, 3, 2, and 1 [25]. Presumably, the nature of this waste is similar to that found in every tank to be processed via SCIX. Those reports appear to be very thorough and are estimated to be sufficient to support process design.

There are no findings or observations for LOI #5.

3.2.1.6. LOI #6. Have disposal paths been identified for all wastes including secondary waste streams?

Condition at Review

The Program has completed a process flow diagram (PFD) and a heat and material balance [26]. It identifies all SCIX process streams, and details the anticipated source, volume, composition, physical and chemical properties, and destination of each stream.

LOI #6 Observation 1: Good Practice

The PFD is comprehensive and complete. Disposal paths have been identified for all wastes including secondary process waste streams.

LOI #6 Observation 2: Area of Concern

The ETR team was not provided any information or documentation regarding disposition of failed/spent equipment and components, such as RMFs, SRD units, IXCs, SMPs, etc.

Recommendation: This information may exist and, if so, should be provided to the ETR team. Otherwise, removal and disposition strategies should be developed and documented.

Benefit: This will eliminate potential generation of orphan waste streams, and ensure compliance with DOE O 435.1 Radioactive Waste Management.

3.2.1.7. LOI #7. Have technology activities to support safety basis development been identified and included in the technology roadmap?

Condition at Review

The SCIX process development Program is at or near the end of its conceptual design phase. The SCIX Program is an Operations Activity [27], and specifically not a project, as defined by DOE Order 413.3A [4]. Nevertheless, the Program remains subject to the requirements of 10 CFR Part 830 [28] and, since the SCIX Program has determined that the IXC and SRD portions of the program are each designated as a "major modification," DOE-STD-1189-2008 [26] is being applied." Both 10 CFR Part 830 [28] and DOE-STD-1189-2008 [26] require specific activities regarding safety basis development to be performed. At the time of the review the *Preliminary Consolidated Hazards Analysis for Small Column Ion Exchange Program* [29] and the *Task Requirements and Criteria* document [30] were available for review. Since the time of the on-site review, the *Safety Design Strategy* [31] and the *Conceptual Safety Design Report* [32] also have become available. Portions of the SCIX Program have been defined as a “major modification” and, as such, DOE-STD-1189-2008 *Integrating Safety into the Design Process* [26], appears to have been appropriately implemented.

The SCIX process has been subdivided into four main component operations: RMF, IXC, SRD, and CPE which includes chemical feed, resin preparation, and balance of plant. The PCHA lists the assumptions on which the safety case is based. Most of the assumptions appear to be derived from process knowledge of the anticipated waste streams and the current set of design parameters. Some are based on assumed operating characteristics (for example, resin loading) and may need confirmation from practice. The assumptions in this latter group are rather conservative, of necessity.

<u>LOI #7 Observation 1: Area of Concern</u>

There are several Open Items and Analyses to Be Performed remaining, as identified on pages 4-1 to 4-2 of the PCHA. The results of these inquiries have the potential of significantly affecting the assumptions used in the PCHA.

Recommendation: Unresolved inputs on the Open Items list and Analyses needing to be completed that have been identified in the PCHA should be completed expeditiously by developing a plan, complete with schedule, and including this plan in the SCIX Program Schedule and the *Technology Maturation Plan* [3].

Benefit : Risk reduction due to mitigation of unforeseen hazards that impact design and implementation.

<u>LOI #7 Observation 2: Opportunity for Improvement</u>

The methodology used in the safety analysis follows DOE guidelines [6, 33]. The review team was large (17 members) and seemed to be rather heavily weighted with contractor staff. In general, review teams have a higher proportion of members unrelated to the program. Nevertheless, the review the PCHA seems to be thorough and of sufficient detail.

3.2.1.8. LOI #8. Is the technology sufficiently mature to support conceptual design activities and the transition to detailed design?

<u>Condition at Review</u>

The SCIX technology includes several key technology elements (CTE's): CST columns, RMF filters, MST sorbent, and ion exchange resin grinding. Given over 10 years of research and development, the CTE's are generally characterized by a high level of technical maturity. Isolated issues have been identified that should be considered for further improving the technology maturity prior to conceptual design. They are listed below.

LOI #8 Observation 1: Area of Concern

IXC technology using resin has been extensively researched via a variety of experimental studies, performance models, and heat transfer modeling. Behavior of the CST (IE-911) ion exchange resin is well understood, and performance models have shown to closely fit experimental data. The Program has done an excellent job of developing this technology. One potentially important shortcoming, however, is the lack of validation of the heat transfer modeling. The heat transfer model appears to be based on reasonable assumptions. Its development and application to the analysis of the CST columns appears to be excellent. But no pilot-scale validation testing has been performed.

Recommendation: Considering the importance of keeping the CST column temperatures below about 65°C to maintain resin stability, it is recommended that a pilot-scale test be done with simulated waste, CST, and an artificial heat source. Data can be compared to model calculations in order to either validate the model or provide a basis for making improvements to the model.

Benefit: The benefit of this recommendation is that confidence in the thermal model calculations can be increased, providing a higher level of confidence that the columns will not overheat. It will also provide insight into the sensitivity of the maximum column temperature to process condition fluctuations. This will be particularly useful in light of unknown effect of RMF's on the CST columns.

LOI #8 Observation 2: Area of Concern

RMF technology appears to be well developed and ready to be included in a conceptual design. The only noted deficiency pertains to the interaction between the RMF and the CST column. Accumulation of material on the RMF plates will increase the pressure drop and potentially decrease the liquid flow rate. This may affect column performance and heat transfer from the column.

Recommendation: It is recommended to perform a mock-up test in which appropriately-scaled RMF filters are put in line with CST columns. Surrogate waste should be used for this test. Flow rate measurements should be made. Ideally, an artificial heat source should be included in the CST columns to determine potential effect of flow decreases on column temperature.

Benefit: Such testing should provide increased confidence for predicting the performance and thermal response of the CST columns.

LOI #8 Observation 3: Opportunity for Improvement

Two viable grinder technologies were presented to the review team. Down-selection has since occurred.

Recommendation: Basis for this down-selection and potential impact on the rest of this process should be documented.

Benefit: If problems occur during the grinding step, such documentation would be useful for rapidly remedying the situation. It also provides a means by which peer review can be used to check the basis for the grinder technology selection.

3.2.2. Design Lines of Inquiry

The "Design" LOIs are focused on the actual conceptual design and implementation of the SCIX system and how it integrates with and impacts other existing systems

3.2.2.1. LOI #9. Has the SCIX Program defined the technical requirements and criteria necessary for conceptual design?

Condition at Review

Assessment of this LOI is based on evaluation of the *Technology Maturation Plan for the Small Column Ion Exchange Program* [3] and the TR&C [30] that were issued in October 2010. In that report, several technical issues and assumptions were listed. Identified issues include effect of nitric acid on the carbon steel components, impact of Cs-loaded CST downstream of Tank 41H, final flowsheet for SCIX, impact of increased shielding over the tank, and required testing that has yet to be completed. Testing topics include MST mixing in the tank, optimization of ion exchange column operation, and a process control evaluation. A number of additional studies were also called out.

LOI #9 Observation 1: Area of Concern

It is agreed that process control evaluation is an important issue. It is particularly important given the in-series configuration of the RMF and IXC units.

Recommendation: Model fluid flow between the RMF and IXC units and validate experimentally if possible.

Benefit: It is important to know how the range of effluent flow from the RMF can effect performance of the IXC units.

LOI #9 Observation 2: Area of Concern

One of the additional studies mentioned, related to thermal modeling. It is stated in the TR&C document to determine bounding thermal conditions in the ion exchange column and the waste tank. However, the thermal model has not been experimentally validated.

Recommendation: As mentioned in LOI #8, thermal testing would increase confidence in the thermal model for the IXC.

Benefit: Improved thermal modeling will reduce the likelihood of the resin being damaged during operations from overheating. This can be accomplished by increasing the accuracy of the bounding thermal conditions. Column geometry changes can be made if necessary to mitigate this problem.

<u>LOI #9 Observation 3 & 4: Areas of Concern</u>

The decision to investigate the effect of CST on the RMF is an excellent idea and is in line with the more general need to understand the interaction between the IXC and RMF units. In addition to CST particulate possibly affecting the RMF filter surfaces, pressure drops through the RMF units may pose process control problems for the IXC. This could be integrated with recommended coupled flowsheet testing in LOI #8 Observation 2.

Recommendation: Perform a truly integrated test linking at least one RMF unit to at least one IXC unit. Flow affects as well as cross contamination issues can be explored.

Benefit: Such a test would provide a broader view of potential impact between RMF and IXC units. Increased pressure drop across an RMF unit may result in significant flow decrease through the IXC units and lead to unacceptable temperature rises.

3.2.2.2. LOI #10. Is conceptual design progressing and are schedules, including technical issue resolution, in place and reasonably achievable?

<u>Condition at Review</u>

Completing conceptual design on or near the current date of completion (11/8/10) appeared achievable. Technology development to resolve technical issues and supply needed design data also appeared to have achievable schedules. Available testing equipment and experienced SRNL staff provided confidence that the results will meet SCIX Program needs.

At the time of the onsite review, fifteen technical reports were scheduled to be completed during September to November, 2010, that include necessary data to complete the ETR, or provide useful information. Additionally, four other reports were identified and requested by the ETR team subsequent to the onsite review meeting. Since the review, a number of these nineteen reports have not been completed as originally scheduled. If the reports are substantially delayed, Program impacts could be incurred. However, SRR indicated that they had scheduled the work such that tests that could impact hardware design will be completed first and in time to support equipment procurements.

LOI #10 Observation 1: Area of Concern

Some delays have been experienced in completion of technical reports. Additional testing may be identified in revisions of the recently completed Technology Maturity Plan [3]. Any new technology gaps and technical risks that may be identified must be given sufficient resources to ensure timely resolution.

Recommendation: Ensure sufficient resources are provided to complete the planned evaluations, analyses, and testing (including emergent work) in time to support design and engineered equipment procurement.

Benefit: Overall programmatic risk reduction in technology, schedule, and cost.

3.2.2.3. LOI #11. Are programmatic risks, including technical risks and issue resolution, identified and appropriate risk mitigation activities identified and incorporated into SCIX Program schedules to provide a reasonable confidence of deployment by the end of 2013?

Condition at Review

A "Pre-Mortem" risk assessment [17] was conducted in July 2010. Ten top technological risks were identified and technology development activities are in progress to mitigate these risks. The Small Column Ion Exchange Program Risk and Opportunity Analysis Report [18] was in progress at the time of the review and was completed on November 1, 2010.

The SCIX Operations Strategy document [34] describes initial Integrated System Testing that will be conducted with simulated feed to validate hydraulic stability, decontamination factors, concentration factors, chemical and thermal stability, and overall performance of the system.

LOI #11 Observation 1: Area of Concern

During the onsite review, the ETR Team was told that it had not been determined whether Integrated Systems Testing would be conducted with water or with simulants. However, the "Handling Strategy" to mitigate two SCIX Moderate risks concerning process performance identified by Winship [18] depends on Integrated Systems Testing using **simulants**. Thus, if the Integrated System Testing is not conducted with simulants, it is believed that significant programmatic risks will be incurred. Not verifying equipment performance with a representative simulant and non-radioactive cesium would create a serious risk to the SCIX Program.

Recommendation: Conduct the SCIX integrated test with a representative simulant containing non-radioactive cesium and process solids and verify desired equipment performance before tank installation. See LOI #4 Observation 3 Recommendation.

Benefit: It is critical to demonstrate that the equipment to be installed in the tank will meet Program requirements. The integrated testing must be conducted with a representative simulant for both the liquid waste (containing non-radioactive cesium) and the process solids including entrained sludge, MST, and CST. In particular, the grinding step should be given at least a final test with the actual CST product that will be used in the process. The benefits of simulant testing were very apparent for the Modular Caustic Side Solvent Extraction (CSSX) Unit (MCU).

<u>LOI #11 Observation 2: Area of Concern</u>

The overall SCIX Program schedule appears very aggressive. For example, vendor quality and schedule performance during design and fabrication of engineered equipment modules should be considered a high risk based on SWPF and Waste Treatment Plant (WTP) experience.

Recommendation: Ensure that the highest risk components are identified and testing, validation, and procurements are planned and scheduled to ensure on-time availability.

Benefit: Significant programmatic schedule risk reduction.

<u>LOI #11 Observation 3: Area of Concern</u>

Additional SCIX programmatic risks exist because the Liquid Waste System previously has not demonstrated the ability to provide qualified salt feed at up to 9.7 million gallons per year [7] and a 6-fold increase in Saltstone Production Facility's processing rate (to support both SWPF and SCIX). While this will most likely not cause the loss of all the potential schedule and cost benefits of the SCIX system deployment, it could dramatically reduce those benefits if the Liquid Waste System cannot at least approach the desired feed rate. See discussion and recommendation under response to LOI #12.

Recommendation: Ensure the feed preparation and saltstone throughput risks are addressed appropriately in risk documents and Program schedules.

Benefit: See LOI #12.

3.2.2.4. LOI #12. Has integration of the SCIX system with existing systems, equipment, and processes been adequately addressed and impacts identified?

<u>Condition at Review</u>

Integration of the SCIX system into existing risers and equipment on Tanks 41H and 40H has been effectively accomplished. Potential DWPF vitrification impacts of Titanium (Ti), Nb, and Zirconium (Zr) from CST and MST have been identified, and appropriate tests on glass properties and performance are in progress. Also, DWPF Chemical Process Cell impacts on hydrogen generation, foaming, and rheology changes are being studied [3].

Integration of SCIX into the overall Liquid Waste System was evaluated during preparation of the Liquid Waste System Plan, Revision 16 [7]. As stated in reference 7, "Although efforts will continue to be made to keep transfers between tanks to a minimum, executing this *Plan* requires more frequent transfers than have historically occurred in the Tank Farm, especially after the startup of SWPF, when large volumes of salt solution will be delivered to the facility. Because of the greatly increased pace of transfers after the startup of SWPF, short downtimes due to unexpected conditions requiring repair will be more difficult to accommodate without impact because the idle time of transfer lines will be reduced."

LOI #12 Observation 1: Area of Concern

Additional SCIX Programmatic risks exist because the Liquid Waste System previously has not demonstrated the ability to provide qualified salt feed at 9.7 million gallons per year and a 6-fold increase in Saltstone Production Facility's processing rate (to support both SWPF and SCIX). Also, the increased salt work in the Tank Farm must be accomplished during the same time frame that sludge processing increases significantly to meet the new DWPF canister production and waste loading goals. While this will most likely not cause the loss of all the potential schedule and cost benefits of the SCIX system deployment, it could dramatically reduce those benefits of the Liquid Waste System cannot at least approach the desired feed rate.

Recommendation: Detailed plans must be developed, documented, and tracked such that a strategy for achieving the aggressive salt dissolution rates and Saltstone processing rate can be achieved while supporting the increased sludge transfers and DWPF production.

Benefit: Reduce the programmatic risk of not achieving the expected benefits of the SCIX system.

3.2.2.5. LOI #13. Have reliability, availability, maintainability, and inspectability of the SCIX system been adequately addressed to ensure successful implementation and operation?

Condition at Review

The *Task Criteria and Requirements* [30] presents an outline of the RAMI requirements of the SCIX Program on pages 65-67. This analysis currently is scheduled to begin in December 2010 with an expected completion date of February 2011. Some testing in support of the analysis is already underway. The RAMI report is an assessment of the expected operability of the overall system. As such, its importance to successful deployment and implementation of SCIX cannot be underestimated. The review team understands that the RAMI is in preparation; once the RAMI is completed it should be reviewed to verify that no changes to the ETR are indicated.

LOI #13 Observation 3: Area of Concern

The RAMI report is an assessment of the expected operability of the overall system. As such, its importance to successful deployment and implementation of SCIX cannot be underestimated. The review team understands that the RAMI is in preparation but without the report in hand for review, a satisfactory conclusion of this ETR is difficult. This should be an area of focus for the formal Technology Readiness Assessment scheduled for July 2011.

4. CONCLUSION

The ETR process did not identify any observations in the "Severe Technical Issues" or "Technical Issues" categories. Several "Areas of Concern" and "Opportunities for Improvement" were identified, as well as some "Good Practices".

The decision by the SCIX Program team to adopt the TRA/TMP process [5] is very commendable and should significantly reduce technical risk. The TMP must be completed in its development to include critical path technology maturation schedules and cost estimates to further reduce risk. This "Good Practice", coupled with the Program's excellent leveraging of past EM-30 technology development efforts will reduce the overall program risk further yet.

For the 13 LOIs, 19 "Areas of Concern" were identified. While specific to the LOIs, they can be categorized into four primary areas:

1. The schedule for deployment, while achievable, is very aggressive. As a result, several key activities that are generally in successor/predecessor relations are being conducted in parallel, such as program documentation, planning, testing, validation, design, and procurement. This scenario is manageable but does introduce significant risk to the program if unexpected events occur.
2. The current planning needs to incorporate use of representative simulants for both component testing and integrated system testing. This is an issue that has been identified in the National Academies of Science review of the EM Program, as well as several program reviews, as a key cause for project delays and poor performance.
3. The current planning appears to include only limited integrated system testing. The SCIX Program needs to have a comprehensive understanding of the component interactions with and impacts to other components, including material carry-over effects. If these interactions are not understood, system control, and thus efficient production, will be extremely difficult to maintain.
4. Overall feasibility of achieving the performance goals may be greatest risk to the Program, even in the event of a completely successful and on schedule deployment of the SCIX system. The ability to provide adequate salt waste feed to meet all of the parallel Liquid Waste System demands has never been demonstrated. Well-developed baseline and alternative strategies for risk mitigation will be necessary.

The summary opinion of the ETR team is that the SCIX system is mature enough to move to conceptual design, and that deployment by the end of 2013 is aggressive but achievable. While there are some technology risks, these can be mitigated with appropriate testing and evaluation. For example, integrated testing of the entire system (i.e. four RMFs, two IXCs, etc.) should be performed, and testing should be conducted using representative simulants, at a minimum. However, as stated above, the greatest risk to the Program may be integration of the SCIX system, coupled with start-up of the SWPF and accelerated sludge transfers and processing in DWPF due to canister production and waste loading goals [7].

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Attachment 1 -SCIX ETR Charter

EXTERNAL TECHNICAL REVIEW – DEPLOYMENT OF SMALL COLUMN ION EXCHANGE (SCIX) SYSTEM AT SAVANNAH RIVER SITE

INTRODUCTION/BACKGROUND

Originator
This External Technical Review (ETR) has been requested by Yvette Collazo, Director, Office of Technology Innovation and Development (EM-30). The acting Chief Technical Officer and SR Field Manager have concurred with the need for this review. The deployment of the small column ion exchange (SCIX) system at the Savannah River Site (SRS) is a key part of the enhanced tank waste strategy for SRS. EM-30 has requested the ETR ensure the maturity of the underpinning technologies of the process and readiness to complete the conceptual design phase currently in progress and move to the next phase of detailed design.

Responsible Organization
The Office of Technology Innovation and Development (EM-30) is responsible for ensuring this ETR is completed. The Office of Waste Processing (EM-31) will serve as the sponsor for the ETR. The ETR lead and the ETR team members will be independent of EM-30, SRS organizations, and organizations involved in the development of SCIX.

Summary Description of SCIX
The SCIX system will provide additional salt processing capability to the SRS Liquid Waste Program under PBS-SR-0014C. SCIX is an in-tank or near-tank sorbent column system to remove cesium, strontium, and select actinides from radioactive salt solutions in waste tanks. At the SRS, the SCIX module will be deployed in-tank, using existing waste tanks for shielding. The low-activity treated salt waste will be sent to an on-site disposal facility. The cesium, strontium, and actinide laden sorbent materials and the high-level waste sludge will be sent to the vitrification facility for immobilization in glass.

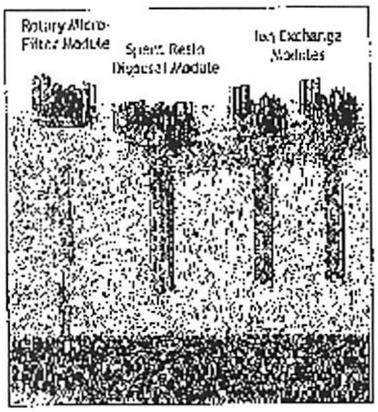

Figure A: SCIX and Rotary Microfilter Modules in a Waste Tank

Deployment of SCIX at SRS will expedite salt waste processing in advance of start-up of the Salt Waste Processing Facility (SWPF) now under construction, reducing the current life-cycle by about six years and $3 billion.

The SCIX system includes several associated components including an Ion Exchange Column, Rotary Micro-filter (RMF), Spent Resin Disposal, and Common Plant Equipment.

The SCIX development and deployment program is nearing the transition from concept finalization and planning to detailed design and procurement. Technology development initiatives have matured the SCIX technology to a system conceptual design stage. Operations are forecast to begin at the end of 2013.

SCOPE OF REVIEW

The purpose of this ETR is to perform an assessment of the status of the technologies underpinning the deployment of the SCIX system. The scope of the review includes the critical technology elements (Rotary Microfiltration, Ion Exchange, Grinder, and actinide removal steps) necessary to successfully deploy the SCIX system. Common Plant Equipment that is used in this SCIX system to perform the same functionality it performs in existing SRS tank farm systems is not a focus of this review. The SCIX flowsheet and specific technology gaps identified to support SCIX system design and deployment by the end of 2013 will be assessed.

Following the issuance of the team's final report, DOE-SR will issue an Issue Response Plan.

MEMBERSHIP

The ETR team will consist of personnel who have not been involved in the EM sponsored activities to develop SCIX and who are not members of the DOE-SR staff or contractor staff (SRNS, SRNL or SRR) assigned to SRS.

Name	Position	Company
Jay Roach	Team Leader	INL
Steven Ross	Team Member	EM-20
Greg Lumetta	Team Member	EM-TBG
Herb Sutter	Team Member	Independent Consultant
Mike Simpson	Team Member	INL
Harry Harmon	Team Member	Independent Consultant
TBD	Observer	EM-50
TBD	Observer	ORP

PERIOD OF PERFORMANCE

The ETR is expected to begin in September 2010 and be completed by the middle of November 2010. The primary deliverables for this work will be an out briefing at the end of the review week, and a final report of ETR review activities and recommendations delivered no later than November 12, 2010. Preliminary timeline activities are listed below:

Sept 13 - 17	Team review of material prior to site visit
Sept 21 - 23	Site visit and review
Sept 23	Team out brief to DOE-SR
Sept 24 – Oct 21	Team develop draft report
Oct 25	Draft report submitted to DOE-SR for factual review
Nov 1	DOE-SR returns comments to Team
Nov 8	Final Report Issued
Dec 2	DOE-SR issues Issue Response Plan

LINES OF INQUIRY

In support of the review, the following Lines of Inquiry (LOIs) are to be considered:

Technology

1) Have technology studies been identified to support conceptual design and/or technology implementation decisions?
2) Are prior EM-30 technology efforts being appropriately used to support conceptual design activities?
3) Has the SCIX Program self-performed a technology maturity assessment to support design efforts and to identify technology gaps and risks for implementation? Has a technology roadmap, such as a Technology Maturation Plan, that includes costs and schedules been developed and implemented with adequate resources?
4) Are plans in-place to perform relevant prototypic large scale testing prior to actual radioactive field deployment?
5) Has the waste that will be processed been adequately characterized?
6) Have disposal paths been identified for all wastes including secondary waste streams?
7) Have technology activities to support safety basis development been identified and included in the technology roadmap?
8) Is the technology sufficiently mature to support conceptual design activities and the transition to detailed design?

Design

9) Has the SCIX Program defined the technical requirements and criteria necessary for conceptual design?
10) Is conceptual design progressing and are schedules, including technical issue resolution, in place and reasonably achievable?
11) Are programmatic risks, including technical risks and issue resolution, identified and appropriate risk mitigation activities identified and incorporated into SCIX Program schedules to provide a reasonable confidence of deployment by the end of 2013?
12) Has integration of the SCIX system with existing systems, equipment, and processes been adequately addressed and impacts identified?
13) Have reliability, availability, maintainability, and inspectability of the SCIX system been adequately addressed to ensure successful implementation and operation?

APPROVALS

We, the undersigned, have read and approve this charter.

Y. Collazo	for T. J. Spears
Director, Office of Technology Innovation & Development	Assistant Manager for Waste Disposition Project

Attachment 1 – Listing of Proposed Review Documents

1) Liquid Waste System Plan
2) Technical Requirements and Criteria (including key performance parameters and key assumptions)
3) Technology Maturation Strategy
4) SCIX Level 1 and Level 2 Schedules
5) Risk Management Plan (including handling strategies)

Attachment 2 -ETR Team Bios

Dr. Harry D. Harmon

Since retiring on January 1, 2008, Dr. Harmon is providing management and technical consulting to the Department of Energy (DOE) and its contractors including assessments such as technology readiness assessments, independent project reviews, and technology development program reviews. Previously, Dr. Harmon served seven years as a Senior Program Manager for Pacific Northwest National Laboratory (PNNL) where he served as the Salt Processing Technology Development Manager at the DOE Savannah River Site (SRS). Prior to joining PNNL, he worked in the private sector as Senior Program Manager for NUKEM and Vice President of Tank Waste Programs at M4 Environmental Management, Inc. Dr. Harmon also served at SRS and Hanford in key senior management positions. At SRS, Dr. Harmon provided expert technical advice and management of technology development for high-level waste program for the Westinghouse Savannah River Company. As the Vice President of the Tank Waste Remediation System Division of Westinghouse Hanford Company, he managed the overall system required to safely manage the waste tanks and process the waste for final disposal. During that time, his organization made significant progress on mitigation and remediation of the high visibility Hanford waste tank safety issues. In previous years at SRS with Westinghouse and DuPont, he held several management positions in Savannah River Laboratory where he directed process and equipment research and development in nuclear fuel reprocessing, actinide processing, waste management, and environmental restoration. His technical expertise is in waste management, nuclear fuel reprocessing, separations chemistry and engineering, and developing and implementing technology in these areas.

Dr. Harmon is a member of the American Chemical Society and Sigma Xi. He has participated in a number of independent reviews for the National Research Council, U.S. DOE, and DOE contractors and has also written a collection of articles and publications on the subjects of actinide chemistry, nuclear fuel reprocessing, and high level waste management. Dr. Harmon earned a B.S. degree in Chemistry in 1968 from Carson-Newman College, Jefferson City, Tennessee and a Ph.D. in Inorganic and Nuclear Chemistry in 1971 from the University of Tennessee in Knoxville. He currently serves on the Board of Visitors of the Chemistry Department at the University of Tennessee.

Dr. Gregg J. Lumetta

Education

B.S. (cum Laude)	Chemistry, 1982	Univ. of Missouri—St. Louis
Ph.D.	Inorganic Chemistry, 1986	Univ. of Missouri—St. Louis

Employer

Battelle, Pacific Northwest National Laboratory

Representative Skills and Experience

Dr. Lumetta has over 20 years experience in the field of radiochemical separations. His research interests include the study of solvent extraction and ion-exchange systems, especially regarding radiochemical separations, the treatment of waste streams, radiological decontamination, and hydrometallurgy. He is a member of the DOE Office of Environmental Management Technical Experts Group. He has served as the Focus Area Lead for the Transuranic Recycle Technology Focus Area of PNNL's Sustainable Nuclear Power Initiative, PNNL technical lead for the Department of Homeland Security Threat Awareness and Characterization Thrust Area, and managed the Separations and Radiochemistry Team in the RPL from 1999 to 2003. He led efforts in developing and testing of the Hanford baseline sludge pretreatment process.

Publications

Dr. Lumetta has authored or co-authored 54 papers in peer-reviewed journals, 51 publicly-released reports, 17 papers in conference proceedings, 72 conference presentations, and 1 book chapter. He has served as editor for 2 technical books with a third in progress.

Affiliations

American Chemical Society, Phi Kappa Phi

Dr. STEVEN L. ROSS

Education

B. Sc. Chemistry, Central Michigan University

Ph. D. Biochemistry, Baylor College of Medicine

Post Doctoral Research, Biochemistry, Case Western Reserve University

Employer

U.S. Department of Energy, Office of Environmental Engineering

Representative Skills and Experience

Dr. Ross has nearly 30 years experience in the fields of high level and low level radioactive waste management, process control, equipment design and fabrication, prototyping, process chemistry and analytical chemistry. For seven years prior to coming to DOE he provided technical support to the Office of Civilian Radioactive Waste Management (RW). This work included development of the Waste Acceptance System Requirements Document, the Integrated Interface Control Document, an analysis of the Accelerator Transmutation of Waste proposal, and analyzed the impacts of a variety of U.S. Nuclear Regulatory Commission regulations on the management of radioactive waste including 10 CFR Parts 60, 61, 63, 72, 73, 74, 835, and 961.

Prior to consulting to DOE-RW Dr. Ross was the Manager of the Solidification Laboratory for Stock Equipment Company that manufacturer a cement-based system for the solidification of aqueous low-level radioactive waste (1979 – 1989). These waste streams are composed primarily of evaporator concentrates and spent ion exchange bead resin slurries, both from commercial power reactors. Dr. Ross wrote the Process Control Plan for seven different power plants. He also led the development of a solidification process using a water extendable carbohydrate polymer for waste streams that are chemically incompatible with the cement system.

Subsequent to Stock Equipment Company, Dr. Ross held several positions within ABB Automation, Inc. (1989 – 1999). These positions include Applications Engineer, Product Line Manager, and Project Manager. In these positions, he developed several process control algorithms for both small and large scale applications, using classical PID and ladder logic controllers as well as state of the art algorithms based on neural networks. Dr. Ross also was on the team that led to ABB Automation (formerly Bailey Controls Company) obtaining its first ever ISO 9000 certification.

Dr. Ross joined DOE's Office of Engineering and Technology in January 2008.

Publications and Patents

Dr. Ross has authored nine journal articles and six patents.

Dr. Michael F. Simpson

Dr. Michael F. Simpson is a senior researcher at Idaho National Laboratory in the Pyroprocessing Technology Department. He received degrees in chemical engineering from California Institute of Technology (B.S. 1991) and Princeton University (Ph.D. 1996). He has been at INL since 1996 when he joined ANL-West to develop ceramic waste form technology for the EBR-II spent fuel treatment project. In the last 14 years, he has been involved with a variety of research projects in the area of pyroprocessing, waste treatment, hydrogen production, and nuclear fusion. He also managed the Pyroprocessing Technology Department for 2 years. His current interests are in separation of fission products from molten salt for application to waste minimization, developing safeguards strategy and technology for pyroprocessing, and general use of modeling to optimize pyroprocessing flow sheets and control schemes. He has extensive experience in studying ion exchange systems, primarily focused on removal of fission products from molten salt using zeolite-A. He has seven publications on this topic (Ref. 1-7).

1. T.S. Yoo, S.M. Frank, **M.F. Simpson**, P.A. Hahn, T.J. Battisti, and S. Phongikaroon; "Salt-Zeolite Ion Exchange Equilibrium Studies for Complete Set of Fission Products in Molten LiCl-KCl;" *Nuclear Technology*, Vol. 171, n.3, September 2010.
2. P. Sachdev, **M.F. Simpson**, S.M. Frank, K. Yano, and V. Utgikar; "Selective Separation of Cs and Sr from LiCl-Based Salt for Pyroprocessing of Oxide Spent Nuclear Fuel;" *Separation Science and Technology*, vol. 43, 2709-2721, 2008.
3. **M.F. Simpson**, T.S. Yoo, R.W. Benedict, S. Phongikaroon, S. Frank, P. Sachdev, K. Hartman; "Strategic Minimization of High Level Waste From Pyroprocessing of Spent Nuclear Fuel;" Proceedings of Global 2007, Boise, September 2007.
4. S. Phongikaroon and **M. F. Simpson**; "Two Site Equilibrium Model for Ion Exchange Between Multivalent Cations and Zeolite-A in a Molten Salt;" *AIChE Journal*, Vol. 52, No. 5, pp. 1736-1743, May 2006.
5. M.L. Gougar, **M.F. Simpson**, and B. Scheetz; "Two-Site Equilibrium Model for Ion Exchange between Multivalent Cations and Zeolite-A in a Molten Salt;" *Microporous and Mesoporous Materials*, vol.84, n.1-3, pp. 366-372, 2005.
6. **M.F. Simpson** and M.L. Gougar; "Two-site Equilibrium Model for Ion Exchange Between Monovalent Cations and Zeolite-A in a Molten Salt;" *Industrial and Engineering Chemistry Research*, 42, 4208-4212 (2003).
7. M.L. Gougar, **M.F. Simpson**, T.J. Battisti and B. Scheetz; "Ion Exchange of Fission Products between Zeolite and Molten Salt;" *Light Metals 2002: Proceedings of the TMS Annual Meeting* (February 2002).

Dr. HERBERT G. SUTTER

Education

A.B. Chemistry, Hamilton College, 1964

Ph.D. Physical Chemistry, Brown University, 1969

Post Doctoral Theoretical Chemistry, Cambridge University, UK, 1970-72

Representative Skills and Experience

Dr. Sutter has more than thirty years experience in the fields of high and low level radioactive waste treatment, separations science, waste water treatment, vitrification, and analytical chemistry. For the past twenty years he has provided technical and programmatic support to DOE's Office of Environmental Management (EM). Dr. Sutter has provided technical assistance to the DOE programs at Hanford, Savannah River, and other sites in: (1) high level waste disposal; (2) vitrification; (3) separation technologies; (4) nuclear waste characterization; (5) technology development); and (6) analytical laboratory management.

From 2007 through the present Dr, Sutter has supported EM's Office of Project Recovery working on technology aspects of Hanford's Waste Treatment Plant. During that time he also helped develop the EM Technology Readiness Assessment (TRA)/Technology Maturation Plan (TMP) Process Guide (March 2008) and led the CD-1 TRA of the Sludge Treatment Project (STP) - Phase 1 Engineered Container/Settler Tube Retrieval and Transfer to T Plant Subproject. From 2005 to 2006, Dr. Sutter assisted EM in the development of a long-term, complex-wide Project Plan for Technology Development and Demonstration. From 2002-2004, as senior scientist for Kenneth T. Lang Associates, Inc. he provided support to EM in several areas including the evaluation of HLW vitrification technologies at Hanford and pretreatment and separation technologies at Savannah River. From 1990-2002, as a scientist for Science Applications International Corporation, he supported EM in the areas of nuclear waste treatment and characterization and analytical chemistry. From 1982-1990, Dr. Sutter was Vice President and Chief Scientist at Duratek Corporation and responsible for technical direction of all Duratek research and development and commercialization programs in ion exchange, filtration and separation techniques. Relevant experience includes: waste water treatment, bench and pilot testing, and waste treatment studies. Dr. Sutter has authored or co-authored over 30 journal articles and technical reports.

Attachment 3 -ETR Team Site Visit Agenda

EM-30 Technical Review of SCIX

Purpose of Visit:

The purpose of this External Technical Review (ETR) is to perform an assessment of the status of the technologies underpinning the deployment of the Small Column Ion Exchange (SCIX) system. Common Plant Equipment (CPE), excluding MST adsorption, which is used in this SCIX system to perform the same functionality it performs in existing SRS Tank Farm systems is not a focus of this review. An assessment of the SCIX flowsheet and specific technology gaps identified to support SCIX system design and deployment by the end of 2013 will be assessed.

ATTENDEES:

ETR Team:

Name	Position	Affiliation
Jay Roach	Team Leader	INL
Herb Sutter	Team Member	Independent Consultant
Gregg Lumetta	Team Member	PNNL (EM-TEG)
Mike Simpson	Team Member	INL
Harry Harmon	Team Member	Independent Consultant
Steven Ross	Team Member	EM-20
Billie Mauss	Observer	ORP

SRR: Dave Olson, Stephen Chostner, Richard Edwards, Terri Fellinger, Pete Hill, Thomas Huff, Tiina Laupa, Pen Mayson, Maria Rios-Armstrong, Karthik Subramanian

SRNL: Kevin Fox, Dave Herman, David Hobbs, Bill King, Dave Koopman, Si Y Lee, Dan McCabe, Michael Poirier, Mike Stone, Zafar Qureshi, Bill Wilmarth

SRNS: Michael Cercy

DOE-SR: Pat Suggs

DOE-HQ: Hoyt Johnson

DOE-ORP: Billie Mauss

WRPS: Kris Colosi, Michael Leonard, Thomas May, Rebecca Robbins, David Swanberg, Leo Ervin Thompson

EM-30 Technical Review of SCIX

Tuesday, September 21st, 2010 [766-H, Room 2136]		*Lead Participants*
7:30 am	Site Access and Badging	
8:00 – 8:15 am	Welcome and Introduction	SRR – Dave Olson, Pen Mayson, Richard Edwards, DOE-SR – Pat Suggs
8:15 – 8:30 am	Purpose of Visit	ETR Team Lead – Jay Roach DOE-SR – Pat Suggs
8:30 – 9:15 am	Integrated Salt Disposition • Supplemental Salt Strategy: Why SCIX? • System Plan Considerations	SRR – Pete Hill
9:15 – 10:00 am	SCIX Management Approach • Program Management Approach • Program Schedule	SRR – Pen Mayson
10:00 – 10:15 am	Break	
10:15 – 11:00 am	Program Overview • SCIX Flowsheet • Resin Selection: Why CST?	SRR – Richard Edwards, Thomas Huff
11:00 – 11:45 am	Technology Maturation Strategy • Hybrid Process • Critical Technology Elements o SCIX Team TRA assessment • Future Testing Overview	SRR – Maria Rios-Armstrong, Thomas Huff SRNL – Dave Herman, David Hobbs, Dan McCabe
11:45 am – 12:45 pm	Lunch	
12:45 – 1:45 pm	Design • Technical Requirements and Criteria • Safety Design Strategy	SRR – Thomas Huff

1:45 – 3:30 pm	CTE 1: Ion Exchange Column
	▪ CST
	  o Historical Background
	  o Loading & Performance
	▪ Thermal Modeling
		SRNL – Bill Wilmarth, Dan McCabe, Bill King, Si Y Lee

3:30 – 3:45 pm	Break	

SCIX ETR at SRS (2/4)

EM-30 Technical Review of SCIX

3:45 – 4:30 pm	CTE 2: Rotary Microfilter • Testing and Performance • MST v. Sludge	SRNL – Dave Herman
4:30 – 5:00 pm	Team Discussion	Team Members
5:00 – 5:30 pm	Daily Outbrief / Future Follow-up Sessions / Actions	SRR – Richard Edwards, Tiina Laupa
5:30 pm	Adjourn	

Wednesday, September 22nd, 2010 [Presentations in 766H, 2136]		*Lead Participants*
7:30 am	Site Access and Badging	

8:00 – 9:30 am	CTE 3: CPE, MST Adsorption
	• MST
	  o Loading & Performance
	• Mixing Studies
	  o $^{1}/_{10}$ Scale Tank
	  o Rheology
		SRNL – David Hobbs, Zafar Qureshi, Michael Poirier

9:30 – 10:15 am	CTE 4: Grinder • Tank 7 - Historical Background • Testing & Performance	SRR – Thomas Huff, Maria Rios-Armstrong
10:15 – 10:30 am	Break	
10:30 – 11:15 am	DWPF Flowsheet Impacts	SRNL – Kevin Fox, Dave Koopman, Mike Stone SRR – Terri Fellinger
11:15 am – 12:00 pm	Risk Management Plan • ROAR • Premortem • Key Technical Risks	SRR – Stephen Chostner
12:00 – 1:00 pm	Lunch	
1:00 – 1:30 pm	Travel to SRNL, 786-A	
1:30 – 2:00 pm	EDL Tour – $^{1}/_{10}$ Scale Mixing Tank	SRNL – Michael Poirier
2:00 – 2:30 pm	Travel to ACTL	

SCIX ETR at SRS (3/4)

EM-30 Technical Review of SCIX

2:30 – 3:30 pm	ACTL Tour – RMF, Rheology, Glass Formulation	SRNL – Dave Herman, Kevin Fox
3:30 – 4:30 pm	Team Discussion	Team Members
4:30 – 5:00 pm	Daily Outbrief / Future Follow-up Sessions / Actions	SRR – Richard Edwards, Tina Laupa
5:00 pm	Adjourn	

Thursday, September 23rd, 2010 [766H, 2136]		*Lead Participants*
8:00 – 9:00 am	Follow-up Discussion – Session 1	SRR – TBD based on Follow-up Session topic
9:00 – 10:00 am	Follow-up Discussion – Session 2	SRR – TBD based on Follow-up Session topic
11:00 -11:45 am	Team Discussion / Outbrief Preparation	Team Members
11:45 am - 1:00 pm	Lunch	
1:00 – 3:00	Outbrief Preparation	
3:00 – 4:00	Outbrief	SRR – Richard Edwards, Karthik Subramanian DOE – Pat Suggs